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KEY TO ENGINES AND ENGINE-RUNNING.

A PRACTICAL TREATISE UPON

THE MANAGEMENT OF STEAM ENGINES AND
BOILERS FOR THE USE OF THOSE WHO
DESIRE TO PASS AN EXAMINATION
TO TAKE CHARGE OF AN
ENGINE OR BOILER.

With numerous Illustrations

AND INSTRUCTIONS UPON

ENGINEERS' CALCULATIONS, INDICATOR DIAGRAMS, ENGINE
ADJUSTMENTS, AND OTHER VALUABLE INFORMATION
NECESSARY FOR ENGINEERS AND FIREMEN.

BY

C.C.

JOSHUA ROSE, M.E.,

AUTHOR OF "THE COMPLETE PRACTICAL MACHINIST," "THE SLIDE-VALVE,"
"THE PATTERN MAKERS' ASSISTANT," "MODERN STEAM ENGINES,"
"MECHANICAL DRAWING SELF-TAUGHT," "MODERN
MACHINE-SHOP PRACTICE."

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PREFACE.

In the preparation of this book the aim has been to confine its contents to matters pertaining to the engine room, and to so present each subject that the student could readily understand it without the aid of a teacher.

The amount of space alotted to each subject, and the method of treating it, has been determined from a consideration not only out of its importance, but also of the difficulty that many are apt to encounter by reason of their education having been limited.

In the parts teaching simple calculations especial pains have been taken to make each subject plain and clear, by the aid of engravings and of explanatory notes placed alongside of the calculations.

This the author believes will be found to have an especial value to the class of readers for whom this book is intended.

Joshua Rose.

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New York City.

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What part of the boiler would you inspect first?

To what defect is a safety valve most liable?

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Is a guage-glass always reliable for showing the height of the water in the boiler?

What would you do to find out if the guage-glass was showing the correct water level?

What is likely to happen if the steam condenses in the boiler without any of the cocks being open?

What parts of the boiler would you clean before lighting the fire?

How would you lay the fire?

Does bituminous or anthracite coal light the easiest?

How soon would you put coal on after the fire is lit?

How much coal would you put on the fire at a time?

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What causes a pump to fail?

How may a stuck valve or check-valve be released?

What would you do if the feed water got so hot that the pump worked imperfectly or not at all?

What causes scale to form in the boiler?

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What are the principal methods employed to prevent the formation of scale in the boiler?

What advantage does a horizontal heater possess?

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Why is it necessary to keep an even temperature in the fire-box?

What determines how thick or deep the fire should be?

Why do the edges of a fire-box require more attention than the middle?

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What parts of the engine would you attend to if the boiler primes?

What would you do if the water got "dangerously low" in the boiler?

In such a case how would you regulate the dampers?

What do you consider "dangerously low"?

What is "blowing down" a boiler?

What is "blowing off" a boiler?

How much would you "blow down" a boiler?

How often would you "blow down" a boiler?

How often would you "blow-off" a boiler?

At what time in the day would you blow down?

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What tools are used in cleaning a fire?

What is the use of each tool?

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What would you do to prevent blowing off if the engine stopped and no steam was being taken from the boiler?

What does blue flame in the fire-box indicate?

How much water would you have in a boiler when leaving it for all night?

How would you leave the fire for the night?

Give a safe method of banking a fire?

How should the dampers be left when the fire is banked?

How would you set the safety-valve for a banked?

What is the first thing to do in starting up a banked fiire?

How would you regulate the boiler feed?

How can a pump be regulated so as to be kept pumping without uncharging the boiler?

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QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART I.

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How low should the pressure get before the water is let out?

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What would you do after the water is all out of the boiler?

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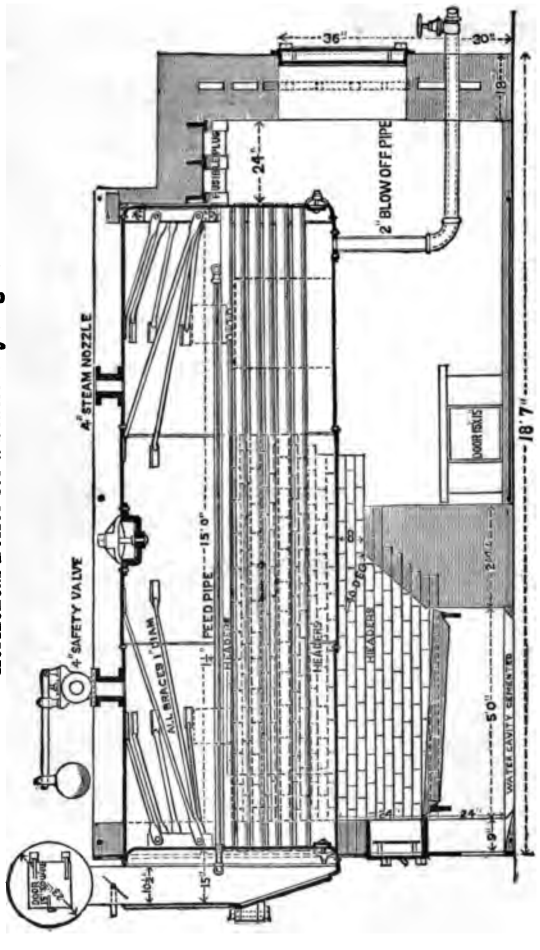


Horizontal Boiler for a Stationary Engine.

PART I.

STATIONARY ENGINE BOILERS.

The First Thing to do in taking charge of a boiler is to know from personal inspection that the safety fittings and the boiler feeding apparatus are in good order.

The Safety Valve is the first thing to inspect as it is liable to stick in its seat especially in cases in which it is set at a greater pressure than is got up in the boiler, because in that case it is not lifted from the seat and in time sticks fast there.

In such cases it is proper to lift the valve at least once a day while steam is on. For this purpose a cord may be attached to the lever, passing over a pulley directly above the lever, and thence to some convenient place near the boiler but where it is not liable to get caught and pulled accidentally.

Before Lighting the Fire see that there is sufficient water in the boiler. If there is a gauge-glass on the boiler it should show three-quarters full, or three-quarters of a glass as it is called.

The Gauge-glass may Show a False Water Level and to be sure that such is not the case, open the top gauge-cock and the cock at the bottom of the gauge-glass letting the water run through the gauge-glass. Open and close the cock below the gauge-glass two or three times to see that the water comes to the same level each time.

If the Steam Pressure has been allowed to fall in the boiler without any of the cocks being opened there will be a partial vacuum in the boiler and air must be let in before the true water level will be shown either by the gauge-glass or by the gauge-cocks.

Opening the upper gauge-cocks will let in the air and it should not be closed again until enough steam has been got up in the boiler to expel the air again, or in other words until steam begins to issue from it.

The Grate Bars and ash pit should be cleaned of clinker ashes etc.,and it should be seen that the tubes are clear of ashes etc., before the fire is laid, if the grate is a shaking one the lever should be applied to see that the grate will shake properly.

To Light the Fire. In the case of anthracite or hard coal, as it is sometimes termed, first cover the bars with a thin layer of coal and then put in pieces of lighted greasy waste (if it is at hand) distributed about the furnace, taking especial care to light the fire at the fire-door end and in the corners because the fire will spread from the front end towards the back easier than it will from the back end towards the front.

The Fire Should Light from the bottom and not from the top hence the thinnest pieces of the wood should be put in first.

If there is any soft coal at hand a small quantity of it will accelerate lighting the fire as it burns easier and quicker than hard coal.

Before Putting on the Coal the wood should be well lighted, the bottom portion of it having ceased flaming.

This Causes the lighted wood to spread over the bars and the fire to light evenly.

Charge the coal lightly, first covering the places that have burned up the most.

The Fire Door should be kept open as little as possible as it admits cold air that is detrimental to the combustion, as well as to the draught, thence firing should be done quickly.

A Good Fireman will maintain as even a tempeature as possible in the fire-box by charging lightly and quickly.

Some Firemen Will, after the fire is at its proper depth all over the grates, charge the fire in the front end, that is at the fire-door end, and push it back, as it burns up, to keep up the thickness of fire at the back.

The Thickness of the Fire depends upon the size and kind of coal.

With Small Coal a fire from 4 to 6 inches deep will answer, while, if the lumps are 5 or 6 inches in diameter, a fire from a foot to 15 inches deep may be maintained as is done in some locomotives.

The Object is to have the fire thick enough to prevent it from burning through in spots or letting cold draughts of air pass through it.

The Sides of the Furnace require particular attention not only because cold air is more likely to get through there, but also in boilers having fire-boxes the cool sides of the box keep the temperature of the fuel down, hence a thicker fire is necessary around the sides than in the middle of the furnace or fire-box.

CLEANING THE FIRE.

Three Things are to be Considered in cleaning a fire, first; that the boiler pressure will fall during, and for a short time after, the cleaning, second; that the depth of fire will be diminished by the cleaning, and third; that the temperature of the fire will fall during the cleaning.

SHAKING GRATE-BARS.

When a Furnace has Shaking Grate-bars the cleaning of the fire is greatly facilitated, and with bars that shake singly, (and good coal) the fire is often not disturbed during the day, except to shake the bars occasionlly, passing the poker through it and using the hoe to keep it evenly spread.

If the Grate Shakes in sections more cleaning will be required to break up the clinker, while if the bars do not shake the cleaning assumes greater importance.

Before Cleaning, therefore, see that there is sufficient water in the boiler that it need not be fed while cleaning, nor just after cleaning, the fire.

Prepare for Cleaning by having a thick fire on the grate so that after cleaning it will burn up quickly, and third, let the cleaning be done as quickly as possible.

THE FIRE CLEANING TOOLS.

The Cleaning Tools are the hoe which is used to push the fire back on the bars, or pull it forward, and pull the clinkers to the surface.

The Slice Bar for slicing or breaking up the fire; the clinker hook for pulling out clinkers and the T bar or poker, these two tools being used for the same purpose, which is to let the ashes down through the bars.

In Cleaning First Use the Hoe (the damper being wide open) pushing to the back of the furnace all the good live coals, drawing the clinker forward within easy reach of the fire tools.

Next Haul out the Clinker and then use the slice bar to loosen, break up and expose any clinker that may be among the fire that is filled at the furnace.

Then with the Hoe spread the fire evenly over the bars again, give it a light charge of coal, and close the fire-door to let the fire burn up a little.

As Soon as the Fire is fairly going again use the **T** bar, moving it back and forth lengthways of the bars, with the **T** part laying in the grate thus **⊥** so that it will lift the fire slightly and cause the ashes to fall through.

If the Fire is Found to be too thin after the cleaning is done it should be restored gradually, building up the brightest places first.

The Draught should be decreased while the fire is being cleaned, but the damper should never be entirely closed, as this might cause an explosion in the fire-box and tubes.

During a Temporary Interruption, as in the case of the engine stopping, partly close all the dampers, as it is wasteful to make steam and blow it off through the safety-valve.

A Blue Flame is evidence of incomplete combustion, but there may be a blue flame and imperfect combustion at the back end of the furnace, and a white flame and perfect combustion at the other end.

This is likely to Occur, with heavy firing, near the fire-door, and a thin fire at the tube-sheet end of the fire-box. In this case the unconsumed gases produced near the fire-door (as evidenced by the blue flame) are consumed in passing over the bright fire at the tube-plate end of the furnace.

LEAVING THE BOILER FOR THE NIGHT.

Always Leave Plenty of Water in the boiler when leaving it for the night, not only to allow for any leak, but also because it gives a fair start in the working and more time to remedy any defect in the feed pump if it arise.

By Plenty of Water very nearly a full guage is meant, or if there is no guage-glass to the boiler let the water stand above the the second or middle cock.

BANKING THE FIRE.

The Usual Method of leaving the fire for the night is to bank it. There is an element of danger, however, in banking a fire, unless it is done to suit the circumstances, because steam may generate very rapidly, and perhaps more rapidly than the safety-valve can carry it off.

A Safe Method is to clean the fire, leaving the clinker and ashes covering the front half of the grate and the fire piled up on the back half.

The Damper and Ash-pit Door should be closed tight, the fire-door open, and the fire well covered with fresh coal, choosing small rather than large coal.

If this Method is found not to keep up the fire sufficiently the same plan may be employed, except that the ashes and clinker may be removed, and if this still leaves too cold a boiler and too poor a fire in the morning, the fire may be left spread over the grate but heavily covered with fresh coal, the draught being stopped as much as possible by closing the dampers and opening the furnace door.

To Further Ensure Safety the weight on the safety-valve lever should be pushed towards the valve, so as to cause the safety-valve to blow off at a less pressure than during the day.

STARTING UP A BANKED FIRE.

In Starting up a banked fire in the morning first close the fire-door and open the damper so as to give the fire all the draught possible, and let it burn up a little, then if it has been piled up at the back of the furnace clean out the ashes by passing the **T** bar beneath the fire, and spread it over the grate, letting it burn up a little before making up the fire.

FEEDING THE BOILER.

The Fireman should endeavor if possible to so regulate the boiler feed that it is kept going as nearly continuously as possible while maintaining a uniform quantity of water in the boiler, and this, with uniform firing, will give the greatest economy.

When Pumps Are Used to feed with, the amount of the lift of the valves can be regulated by a screw, so as to vary the amount of water the pump will deliver, and in this case, it is comparatively easy to set them, so that the pump may be kept going without putting too much water in the boiler.

When Injectors Are Used, however, the feed will be intermittent, and a uniform quantity of water in the boiler is best obtained by feeding at short intervals, stopping the feed when the fire-door is opened much, as when cleaning the fire.

If The Feed Water Is Dirty the gauge-glass should be kept clean by first shutting off the upper cock and opening the lower one, so as to let the water blow through the lower cock, and then shutting off the lower cock from the boiler, and opening the upper one, which will let the steam blow all the water out of the glass. This should be done two or three times a day, so as to keep the holes in the boiler, and those in the cocks from closing up with fur or scale.

If The Water Falls in the glass, or if the gauge cocks show the water to be falling, notwithstanding that the feed pump has been started, it is evident that the pump is not working.

This May Occur from a stuck valve; a leak in the suction pipe, from the feed water being too hot, or from the pump failing to start in action from leaky or choked valves.

A Stuck Valve may generally be relieved by striking a few blows on the outside of the pump with a hammer and a block of wood, or if this does not answer, with the hammer only. Check valves are the ones most likely to stick.

If a Pump Fails to Work by reason of the feed water being too hot, the remedy is to open the pet-cock to let the steam out of the pump, but if this does not succeed, cold water may be poured on the outside of the pump which will start it, after which, in most cases, the pump will keep going and the pet-cock may be closed.

If the Suction Pipe has a joint, a leak there will impair the action of the pump, and, if the leak is great enough, will stop it, the remedy is make the joint tight.

Plunger Pumps Sometimes Fail to act, because the plunger has worn so small in diameter, that there is sufficient air between the plunger and the pump barrel to expand and compress without lifting the valves; the remedy is obviously a new plunger of as large diameter as the pump gland will admit of, boring the gland out to admit the new plunger.

BLOWING OFF THE BOILER.

All the Impurities in the water are obviously left in the boiler when the water has evaporated, and it is obvious these impurities must be blown off or they will form scale on the internal surface of the boiler and the external surface of the tubes or flues.

This scale obstructs the passage of the heat from the iron to the water, and if let get thick enough, will cause the iron to rapidly burn out.

To Prevent the Formatiom of Scale two principal methods are employed, one being to purify the feed water, and the other to occasionally blow the impurities out of the boiler.

Feed Water Heaters generally serve also as purifiers and their effectiveness is increased in proportion as the water can pass quietly through them, and has a large area on which the impurities can settle. Horizontal heaters have the advantage that they have a large settling area, and a less distance for the impurities to fall through before.

LOW WATER.

The gauge-glass and the lower gauge-cock are usually set so as to have a margin of about three inches of water above the tubes or crown sheet of the fire-box, hence if it is known that the water is but just below the bottom of the gauge-glass or gauge-cock, there is no positive danger, although it is improper to let it get so low.

If the Water is Out of Sight and it is not known exactly how low it is, then it is dangerously low, and every minute is of vital importance.

Should the Water get Dangerously Low in the boiler the most dangerous thing to do is to lift the safety-valve or pump in cold water, especially if it is not known how much water there is in the boiler.

As quickly as possible cover the fire with ashes, coal, earth, sand, or anything that is at hand that will smother the fire, and close the draft to the fire, leaving the fire-door and the chimney damper open.

Leave all the Steam Outlets Just as they are, and also the feed.

PRIMING.

Priming, which is also called "Foaming," is that the steam carries up water into the steam space. This may arise from several causes, but it is well known that what will stop priming in some cases will cause it in others.

The Known Causes of Priming are, first; too little room for the steam in the boiler, and it follows that a high water lever may cause priming, second; it may be caused by a difference of temperature between the water and the steam in the boiler. Suppose, for example, that the pressure of the steam and water in the boiler is 160 lbs. by guage, and its sensible temperature will be 370 degrees. Suppose then that enough steam is permitted to escape from the boiler to reduce the steam pressure to 140 lbs., and its temperature will be reduced to 361 degrees. But the water will remain at 270 degrees and the result will be that it will pass into steam so rapidly that it will carry up the water and hold it in suspension in among the steam. The water will pass with the steam into the engine cylinder, and the boiler will be said to "prime" "foam" or "work water." The same thing may happen if the water is heated very rapidly.

Priming is Wasteful because it rapidly empties the boiler of its water, and dangerous because it may cause the piston to knock out the cylinder-head or. cover.

When the Safety-valve blows off priming may be induced, especially if the engine is at work, because in this case the boiler is being forced, or, in other words, is making steam more rapidly than it is designed to do, and the passage of so large a body of steam through the water is apt to lift it.

Muddy Water will sometimes cause foaming or priming, as will also insufficient circulation of the water in the boiler or sometimes the presence of grease or oil.

Priming may be Detected from the discharge of water with the steam when the guage-cock is opened, the steam looking white and fluttering as it escapes, and also by violent motion of the water in the guage-glass, or by a thump or pound at the ends of the piston-stroke.

To Stop Priming the steam from the boiler should be decreased by slackening the speed of the engine, or if necessary, by stopping it. The true water level can then be seen and if there is too much water in the boiler some of it may be blown off, while if the quantity of water in the boiler will permit it, the feed may be put on.

If the Boiler has a surface blow off cock, or a mechanical boiler cleaner, it is best to blow off from that, as it carries off the scum at the same time as relieving the boiler.

To Prevent Priming a steady and uniform rate of boiler feed, the use of pure water, a clean boiler, and steady firing are the best means, turning on the steam slowly so as not to violently disturb the water in the boiler.

The Engine as well as the boiler requires attention when the boiler primes. Thus the cylinder cocks should be opened to let out the water from the cylinder and prevent breakage.

CLEANING THE BOILER.

The Steam Leaves behind it all the impurities that the water contained, and these impurities deposit in form of mud and scale, which must be got rid of because it causes a loss of fuel, and if allowed to get thick enough will cause the boiler to burn.

The use of Boiler Compounds or scale preventatives may be resorted to with advantage, providing they are of a nature to suit the water, but mechanical cleaning must also be resorted to at periods determined by the nature of water.

Boilers are cleaned in Two Ways, first; by blowing off the impurities before they have formed into scale, and second; by removing at certain intervals, whatever scale has formed.

Blowing Down may be done in two ways, first; from the surface of the water by means of mechanical cleaners, and second; by blowing out from the bottom of the boiler.

The First draws off the impurities as they are thrown to the surface, the second draws them off after they have become more condensed and sink to the bottom.

How Often a Boiler should be Blown Down depends upon the kind of water fed to the boiler, where purifiers are used less blowing down is obviously needed.

It is Best to blow off from the bottom of the boiler when no steam is being used, as during dinner time, letting the water blow down about a quarter of the glass, or from the upper to the middle guage-cock.

As no Steam is Being Used the feed can then be put on to restore the quantity of water without reducing the temperature of the boiler so much. The feed should be gradual and the fire regulated to keep the steam pressure even.

WASHING OUT AND SCALING THE BOILER.

How Often a Boiler should be Washed Out and cleaned depends upon the quality of water it uses, and varies from about once a week to once a month, according to whether bad and unpurified water or purified water is used.

The First thing to do is to draw the fire, leaving the chimney damper open and closing all the other dampers so that as little cold air as possible can get into the boiler, while the heat can pass away up the chimney.

Let the Steam and Water all remain in the boiler until there is a guage pressure of about 5 lbs. in the boiler.

Then Open the Blow off cock and let out the water. If the water is blown off under a high pressure, then after the waste is all out the iron is hot enough to dry up the scale making it hard and very difficult to remove.

After all the Water is Blown Off take out all the mud plugs and the man-hole and hand-hole covers, and wash out the boiler under as much water pressure as can be had, directing the hose so to reach all parts of the boiler and tubes, and continuing the washing until the water leaves the boiler clean.

Then with a wooden hoe on a piece of gas-pipe of small diameter for a handle, and small enough to pass through the hand hole, draw all the loose scale to the hand hole and remove it, letting the water run slowly so as to carry the small pieces of scale towards the hand hole as fast as the hoe disturbs it.

Then Get Inside the Boiler and a few blows with a light ball-pened hammer will loosen the scale, and a steel scraper will remove more, which must be washed down and drawn out with the hoe.

After the Cleaning and Scaling is complete the engineer, with lamp in hand should carefully examine the interior of the boiler and of the fire-box paying especial attention to the stays to see that they are not broken.

The Hammer Test should also be applied. It consists of sounding the boiler by light blows given by a light ball-pened hand hammer the sound indicating defective places.

* * *

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART II.

Name all the parts of a simple or plain D slide-valve engine beginning with the cylinder?

Into what three divisions may these parts be divided?

What parts constitute the valve motion or valve gear?

What parts constitute the driving or power transmitting mechanism?

What is the meaning of the word " Clearance " as applied to an engine cylinder?

Name the attachments used upon an engine cylinder to lubricate the piston and valves?

What is the difference between a cylinder "Pet-cock" and a cylinder "Relief-valve"?

What is a "Jacketted" cylinder?

What is a "Releasing" valve gear?

What is a "Positive" valve gear?

What is the "Lead" of a valve?

What is the "Lap" of a valve?

What is the "Point of Admission"?

At what point in the valve travel does "Cushioning" begin?

What is a piston "Follower"?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART II.

CONTINUED

What are the two principal kinds of connecting-rods?

What effect does the "Angularity" of the connecting-rod have on the piston motion?

Is this effect increased or diminished by shortening the connecting-rod?

What is meant by the term "Cutting" as applied to a journal or bearing?

What is a "Center Crank"?

What is the difference between a crank and a crank disk?

When the crank is at its point of full power is the piston in the middle of the cylinder?

Is it nearer to the crank-end or the head-end of the cylinder?

What causes this irregularity of the piston motion?

What constitutes the "Live Steam" period of a piston?

What is the "Point of Cut-off"?

What causes the steam to be worked expansively in an engine cylinder?

What are the points of "Release" and of "Compression"?

What is a "Double-ported" valve?

What is a "Griddle" valve?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART II.

CONTINUED

What is a "Balanced valve"?

What is a "Piston-valve"?

What is a "Cut-off valve" and what event does it control in the disposition of the steam to the cylinder?

How is the point of cut-off varied when a cut-off valve is used?

What is a "Throttling" governor?

What is an "Isochronal" governor?

What is a "Forward" running engine?

What is a "Backward" running engine?

How would you proceed to start a plain slide-valve engine?

What is the best position for the crank to be in to start the engine and why is it the best position?

What would constitute a complete examination of a plain slide-valve engine?

In what order should such an examination be made?

How would you take a lead for adjusting the fit of a bearing to its journal?

How would you test the lead of a valve?

What is the first thing you would do in taking charge of an engine?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART II.

CONTINUED.

What would constitute the least permissible examination of an engine with a due regard to safety?

How would you proceed to find if the clearance in the cylinder was equal at each end?

Is it proper to "Square" a plain slide-valve?

How does the wear of the parts affect the lead in vertical engines?

What would you do if the crank-shaft bearings began to heat?

What are the principal causes of hot crank-pins?

At what part of the cylinder-bore should the split of a piston-ring be placed?

How tight should a piston-ring fit to the cylinder-bore?

Why is square or oval packing preferable to round packing for a stuffing-box?

Which guide-bar is the most difficult to oil, the top or the bottom one?

Is there any difference between the action of a plain slide-valve and a piston valve if both have the same amount of lap, lead and travel?

PART II.

THE STEAM ENGINE.

The Steam Engine, in whatever form it exists, consists of a frame or bed-plate carrying at least two distinct mechanisms, first, the driving, or power transmitting, mechanism, and second, the valve-gear or valve-motion, and to these are added such other mechanisms as the nature of the duty the engine is to perform, may require.

The most prominent of these additional mechanisms is a governor for regulating the speed at which the engine is to run; nearly all steam engines require a governor in some form or other, while for electric lighting and some other purposes, it constitutes the main feature in the design of the engine.

Figures 1 and 2 are side views of a Common Slide-Valve Engine, and figure 3 is a plan with the cylinder and bed-plate shown in section.

The Piston, piston-rod, cross-head, connecting-rod, crank, crank-shaft, and fly-wheel constitute the driving or power transmitting mechanism.

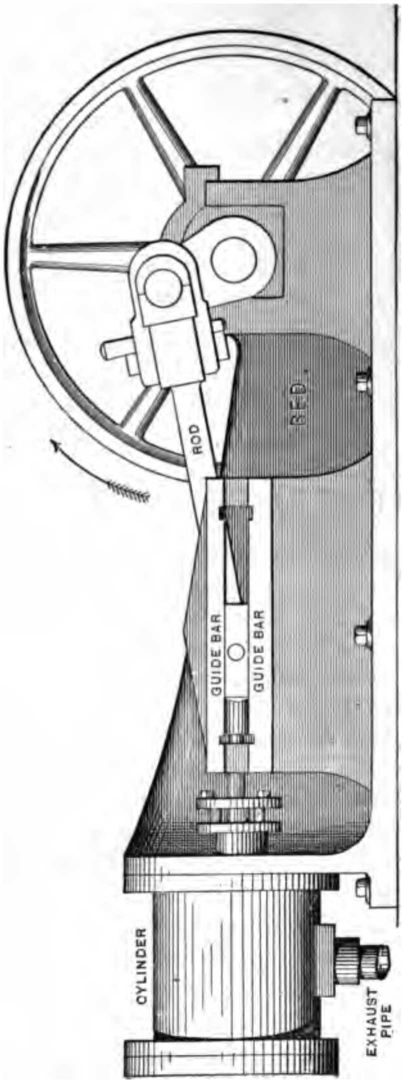


Fig. 1.

Horizontal Engine with Common D Slide-valve.

Side View Showing the Connecting-rod and Guide-bars.

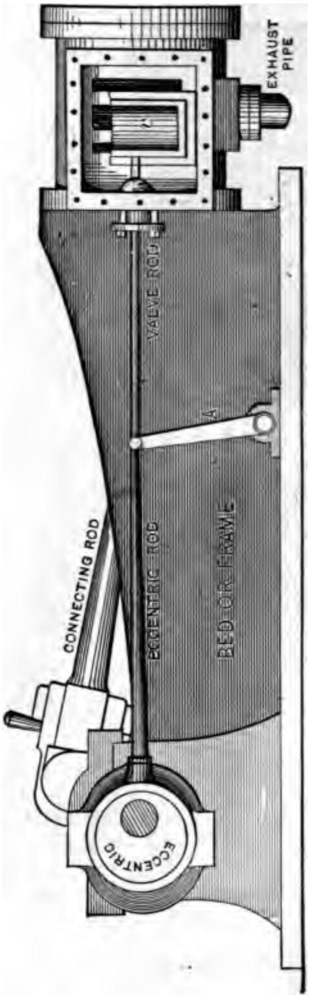


Fig. 2.

Horizontal Engine with Common D Slide-Valve.

Side View Showing the Valve and Steam-ports.

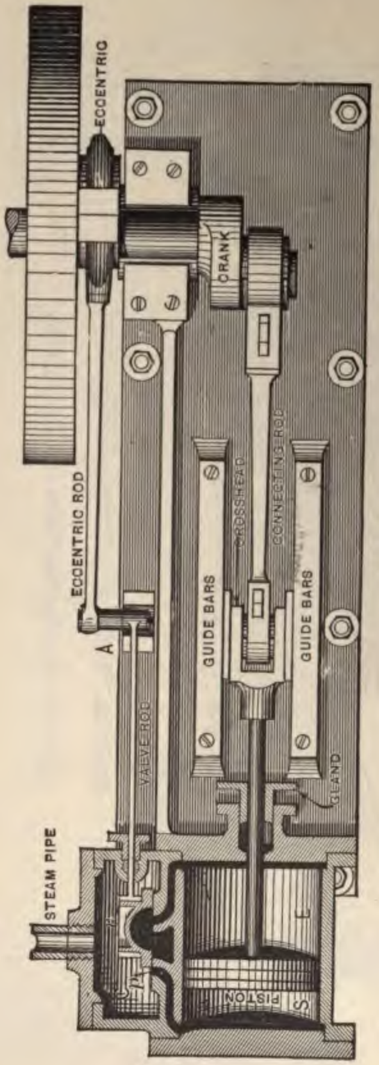
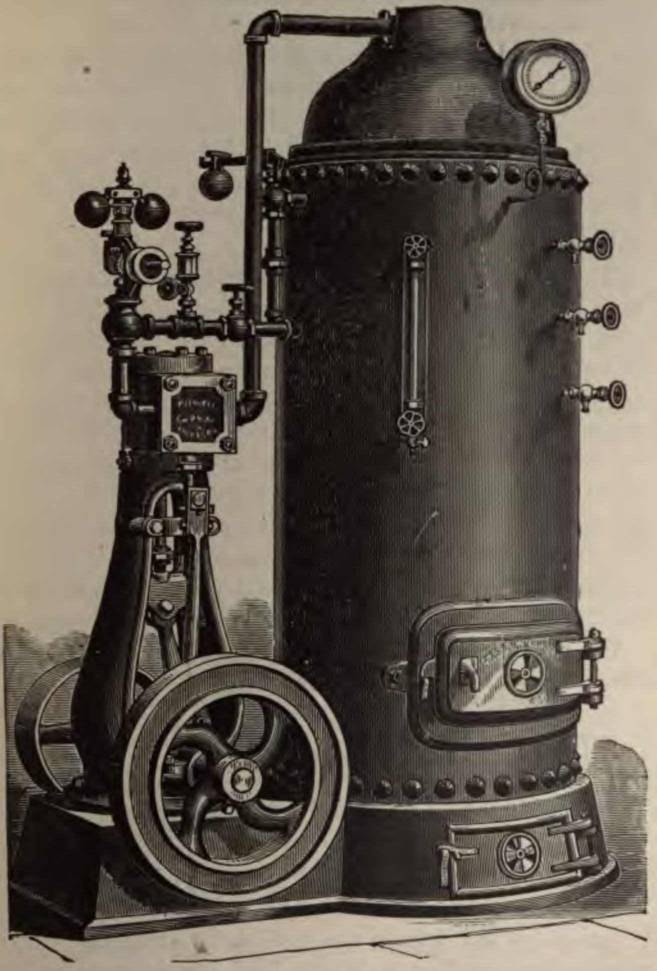


Fig. 3.

Horizontal Engine with Common D Slide-Valve.

Section through the Center of the Cylinder and Valve.



Vertical Engine and Boiler.

The Valve Gear, or Valve Motion consists of the eccentric and its strap, the eccentric-rod, the valve rod guide A, the valve rod or valve spindle, and the valve V, these parts controlling the admission of steam to one side of the piston, and the exhaust from the other.

The steam side of the piston is that against which the steam is pressing, as side S in the figure. The exhaust side E of the piston, is that on which the steam is passing out or exhausting.

The Governor, for a common D valve engine, regulates the engine speed by varying the opening in the bore of the pipe, through which the steam passes from the boiler to the steam chest; leaving a wider opening in proportion as the engine runs slower, and reducing the opening when the engine runs faster. Assuming the engine to be running at its slowest, or its load to be so great that a full supply of steam is required in order to keep the engine up to its proper speed, and the governor will be open at its widest, so that all the further action the governor can have, is to reduce the steam pipe opening, and thus cause the pressure in the steam chest to be less than that in the steam pipe.

This Action is called Wire-Drawing the steam, and the governor is called a **throttling** governor.

THE PARTS OF A STEAM ENGINE.

An Engine Bed or Bed-Plate is a frame that is seated or bedded to its foundation along its whole length.

An Engine Frame is seated to its foundation at two or more places, but not continuously throughout its length.

Bed-plates and frames are necessarily subjected to two principal strains, first, a longitudinal strain that endeavors to push the cylinder and main bearing apart, and second a vertical strain which is at its greatest when the crank is in its positions of greater power, and is caused by the angle at which the connecting-rod stands to the length of the bed.

Frames, with a Single Main Bearing, are subjected to a third strain caused by the leverage of the crank-pin to the main bearing, and acting to bend the frame sideways.

An Ideal Engine Frame or Bed, would, therefore, be one which is not deflected by the expansion and contraction of the cylinder, and in which there was equal strength both above and below a line passing from the center of the crank-shaft through the axis of the cylinder bore, and equal strength on each side of such a line, the crank having journals on both sides of the crank-pin and connecting-rod, while the metal is disposed in the direction of the strains.

Accessibility to the cross-head, guide-bars, etc., however, becomes more difficult in proportion as they are enclosed within the frame.

Frames or beds, with one crank or crank-disk, require more strength on the fly-wheel side than on the other side of the frame, because the main bearing is on that side.

When the guide-ways for the cross-head are in the frame, they are subject to any spring or deflection that may exist in the frame from the strains.

THE CYLINDER.

Cylinders are secured to the engine frames in three principal ways, as follows: by bolting them down to the bed-plate; by bolting them to one end of the bed-plate so that they may expand and contract without springing the bed-plate, and, in vertical engines, by bolting them to the top of the frames.

The bores of cylinders require to be parallel so that the piston-rings may fit to the bore without requiring to expand and contract in diameter at different parts of the stroke.

The Sizes of Cylinders. Cylinders are designated for size by the diameter of the cylinder bore and the length of the stroke, thus a 10 × 12 cylinder has a piston of ten inches diameter and 12 inches stroke.

The Wear of a Cylinder Bore, is (if the engine is kept in proper line, and the piston-rings or packing-rings, as they are sometimes termed, fit to the bore with an equal pressure throughout the stroke), greatest near the middle of the length and least at the ends of the stroke. But when the piston-rings are set out by the steam pressure, and the point of cut-off occurs early in the stroke, the wear may be greatest at the ends of the cylinder bore, because of the pressure of the steam diminishing during the expansion.

The counterbore of a cylinder is a short length at each end of the cylinder, that is made of larger diameter than the rest of the bore, so that the piston head may travel completely over the working bore and thus prevent the formation of a shoulder at each end of the cylinder. Such a shoulder forms when there is a part of the bore over which the piston does not pass The length of the counterbore should exceed the amount of the taper on the connecting-rod key, so that as the connecting-rod length alters from the wear, the piston shall not strike the cylinder head.

The Clearance of a Cylinder is the amount of space that exists between the face of the piston when it is at the end of its stroke, and that of the valve when it covers the port, the piston being at the end of the stroke, and as this space exists at each end of the cylinder, the total clearance for a revolution is twice the above amount.

The clearance at the crank-end of the cylinder, is reduced by the piston-rod passing through it.

The Amount of Clearance may be measured by the following method, which has been given by Professor, John, E. Sweet:

See that the piston and valves are made tight, and the valves disconnected; arrange to fill the clearance spaces with water through the indicator holes, or holes drilled for the purpose. Turn the engine on the dead center; make marks on the cross-head and guide that correspond; weigh a pail of water, and from it fill all the clearance space. Weigh the remaining water, so as to determine how much is used. Then weigh out exactly the same amount of water, turn the engine off the center, pour in the second charge of water, and turn back until the water comes to the same point that it did in the first case. Make another mark on the cross-head, and the distance between these marks is exactly what you really wish to know; that is, it is just what piston-travel equals the clearance. This gives the proportion that the clearance space bears to the space in the cylinder, occupied by the steam at the end of the piston-stroke. Thus, if it takes one pound of water to fill this space, and to admit another pound of water, the piston must be moved one inch, then the clearance bears the same relation to the capacity of the engine as one inch bears to the stroke of the piston. Thus, under these circumstances, in an engine of ten-inch stroke, it would be said the engine had ten per cent. clearance.

When a Cylinder is to be Rebored the boring bar should be set true or central to the circumference of the counterbore, so that the bore of the cylinder may be brought to its original position with reference to the bore of the stuffing box.

In determining the proper thickness of a cylinder the reboring must be taken into account, and an allowance in the thickness made for it.

Rule for finding the proper thickness of a cylinder:

Multiply the diameter of the cylinder in inches, by the pressure of the steam in lbs. per square inch; divide the product by 4,000 and to the quotient add $\frac{1}{2}$.

Cylinders require lubricating both to avoid friction and wear of the cylinder bore, as well as of the valve and valve seat. The amount of lubrication required, depends upon the degree of tightness of the piston-rings; upon the speed of the piston; upon the amount of pressure of the valve to its seat and upon the method of operating the slide-valve.

Cylinders with Releasing Valve Gears require freely lubricating because the closure of the valve depends upon the dash-pot, and undue friction retards the closing motion.

The Less the movement of the valve at the moment of its release, the easier it is to move it, because the friction is less and less lubrication is required.

Cylinders are lubricated by Automatic oilers placed on the steam pipe of the engine, the oil being distributed over the surfaces by the steam.

Cylinder oilers sometimes have a pump to force the oil in, and in others the steam in the oiler condenses, and the water thus formed floats the oil over the top of a tube, or up to an orifice through which the oil gradually feeds as the condensation proceeds.

In Other oil feeders, the feed is regulated by increasing or diminishing the opening through which the steam passes from the cup to the steam pipe.

Sight Oil Feeders are those in which there is a glass tube or body, in which the passage of the oil can be seen as it drops.

Cylinder Pet-Cocks are employed at each end of the cylinder to let out the water that condenses from the steam when admitted to a cold, or partly cooled, cylinder. The two cocks are usually connected together by a rod, so that both may operate together.

Cylinder Relief-Valves are valves at each end of the cylinder to relieve the cylinder from the charges of water that sometimes enter from the boiler with the live steam.

Figure 4 shows the relief-valves employed on the cylinder of the Buckeye Engine. It consists of a valve held to its seat by a spiral spring whose tension is sufficient to keep the valve to its seat under ordinary pressure, the excessive pressure from a charge of water, however, will open the valve and let the water escape. This valve also serves the purpose of a pet-cock, because, by operating the arm *a* the valve is opened, and the water, formed on first starting the engine, escapes. The arms *a* of the two waste-cocks or relief-valves are connected together so that the valves at each end of the cylinder may be operated simultaneously by a single rod.

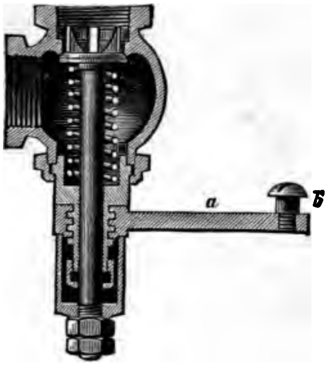


Fig. 4.

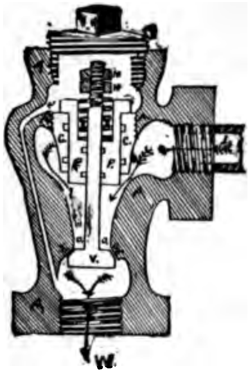


Fig. 5.

Dingley's Automatic Safety-Cock is shown in Fig. 5. The water from the cylinder enters at I, as shown by the arrow, aud escapes past the valve V. When the water has escaped and steam begins to pass out, its expansive force acts on the area of the piston P, causing it to lift the valve and close it. This action is due to the piston P being greater than that of the valve V.

The spiral spring B is of just sufficient strength to support valve V, and is only intended to take off or ease the ramming action of piston P, as also to give way when water pours through inlet I. At the exhaust of every stroke the valve V and piston P fall back and assume the position shown in the figure, leaving V hanging just clear of the seat.

Should Water appear again after the engine is started, the operation, as before described, is gone through with again.

CYLINDER PORTS.

Steam Ports give a quicker admission in proportion as their length is increased, and this reduces the amount of valve travel, and are sometimes given a length equal to the diameter of the cylinder bore.

The bottom of the steam ports are sometimes so placed as to be below the level of the cylinder bore so as to drain off the water of condensation of the steam.

Rule to find the required area of steam port: Multiply the area in square inches of the piston, by the number opposite to the given piston speed in the following table:

Speed of piston in feet per minute.	Number by which to multiply the piston area.
100	0·02
200	0·04
300	0·06
400	0·07
500	0·09
600	0·1
700	0·12
800	0·14
900	0·15
1000	0·17

The cylinder exhaust port must be open when the valve is at the end of its travel, to an amount equal to the width of the steam port, but what this width will be in any given case depends upon the width of the bridges, the amount of the steam lap and the travel of the valve, as will be explained with reference to the slide-valve.

JACKETTED CYLINDERS.

Jacketted Cylinders are those in which there is a space around the cylinder that is filled with live steam.

The Object of Jacketting is to prevent the loss of heat from the steam within the cylinder, by radiation. The steam in the jacket should be received direct from the boiler and should not be drawn from the jacket into the steam-chest because the jacket reduces its temperature and condenses it.

The Water of Condensation of a steam jacket should not be allowed to accumulate in any part of the jacket, but should drain off and pass back to the boiler. To render the jacket as effective as possible, it should extend from end to end of the cylinder, the exhaust steam-pipe leading directly away, so as to have as little communication with both the cylinder and the jacket as possible.

The jacket should have open communication with the boiler at all times, so as to have the pressure in the jacket at the same pressure as that in the steam chest, while the cylinder being kept hot, it will be unnecessary to blow steam through in order to warm the cylinder when starting the engine. The steam should enter the jacket at the highest point so as to prevent the accumulation of air in the jacket. Or, if the steam is admitted at some other point, it should be so arranged as to permit its thorough circulation in the jacket. When a jacket is used the metal of the cylinder body should be as thin as possible, because the transmission of heat through the metal is, both in time and quantity, inversely as the distance or thickness passed through.

The steam in the jacket should be as dry as possible, so that all wet steam admitted during the live steam period may be evaporated by the heat received from the steam in the jacket. The outside of the jacket should be thoroughly protected from cooling by being lagged or clothed with felt, or some other material that is a non-conductor of heat.

From Experiments made by Mr. Charles, A, Smith, of St. Louis, it was found that the amount of variation of temperature that occured during the stroke in a locomotive cylinder, was inversely proportional to the speed of Engine revolution, which shows the advantage of Jacketting Cylinders and of lagging them. as well as the advantage of a high rotative speed.

A Lagged Cylinder is one clothed, which is sometimes done with wood or metal strips, leaving an air space around the cylinder, while in others this space is filled with felt, or some non-conducting material.

Experiments made by Charles, E. Emery, gave the following general results: The thickness of the pipes and of the non-conducting materials were kept constant.

Hair felt was the best non-conducting material of all those tested, and the value of a thickness of two inches of hair felt was taken as unity, and the maximum.

The value of two inches of mineral wool as a non-conductor was 0·832 of hair felt; two inches of mineral wool and tar was 0.715. Two inches of sawdust, 0.68; two inches of a cheaper grade of mineral wool, 0.676; charcoal, 0.632; two inches of pine wood, across the grain, 0.553; two inches of loam, 0.55. This was from the Jersey flats, and almost all vegetable fibre not yet become compact. Slacked lime, from the gas-works, expressed decimally, with hair felt as unity, 0.48; coal ashes, 0.345; coke only, 0.277, the same as used for fuel; two inches of air-space, only 0.136, which dashes a great many people's hopes, and is as interesting as any part of the data; two inches of asbestos, 0.363; two inches of Western coke, about the same as the other coke; two inches of gas-house charcoal, 0.47.

These are very interesting, particularly so this matter of an air-space. It has been supposed that an air-space around a pipe is as good as anything we can have. The fact is, convection or circulation takes place; the air is cooled on one side of the space, descends, and rises on the other, and it is necessary to break up the air-space, and that undoubtedly accounts for the efficiency of these different materials. It is the air, probably, that is the non-conductor; but it should be kept quiescent instead of being allowed to circulate. The air-space itself is of very little value until the circulation is prevented.

THE PISTON.

In calculating the power of an engine it is the piston speed that is taken into account and not the length of the stroke, the latter being used merely in order to obtain the piston speed.

Long Strokes are employed upon engines running at moderate piston speeds, as, from 300 to 450 feet per minute, and short strokes for piston speeds from 350 to 800 feet per minute.

The Porter Allen Engine has been run noiselessly at 1100 feet of piston motion per minute.

In Determining the stroke of an engine the nature of the valve operating mechanism is taken into account.

In releasing Mechanisms, or those in which connection between the eccentric-rod and valve-spindle is broken in order to permit the valve to close quickly, too high a speed of revolution may cause the tripping mechanism to fail to act, hence, a high piston speed is obtained by means of employing a comparatively long stroke.

In Positive Valve-Gears, or those in which the valve is controlled throughout the whole of its movement by the eccentric, the valve mechanism may operate quicker witho danger of missing, hence the piston speed may be greater.

When the stroke equals the diameter of the cylinder bo the cylinder presents the least amount of exposed surface i poportion to its cubical contents.

To Obtain the same amount of expansion in a short, as in a long stroke engine, the steam must be expanded through an equal proportion of the stroke, thus if the steam is cut off at half stroke in both cases, the amount of suspension will be equal.

Pistons are made an easy fit to the cylinder bore, a steam tight fit between the two being obtained by means of the piston-rings.

Solid pistons are provided with Snap piston-rings.

Piston Rings should be tapering in thickness, the thickest part being opposite to the split, and the thinnest at the split. This causes the ring to conform itself to the cylinder bore, and makes it set more evenly around its whole circumference. Rings are made larger in diameter, than the cylinder bore, in the proportion of about $\frac{1}{8}$ inch per foot of diameter, the split being closed when the ring is sprung into place in the cylinder. But if made of brass, the split must be left open enough to allow for the expansion or otherwise, the ring expanding more, then the cylinder will sieze, and cut single.

The Split, of a piston-ring, should be placed on the bottom of the piston (in a horizontal engine) so that the piston-head, in resting on the cylinder bore, will cover up the opening of the ring.

When two or more rings are employed, the splits may be placed on the lower half of the cylinder, so as to cover up their splits as much as possible.

An Excellent form of split or joint for piston-rings, is shown in Fig. 6, the faces fitting from B to D. To make such a joint, the piston is made larger than the cylinder bore to an amount equal to the distance from the face D to B, and on one side of a line drawn across a ring, a piece is cut out. On the other side of this line, and on the other side of the ring, another piece is cut out, and a split is made through the line, whereupon the ring be sprung together. It is then put in place in the piston and closed by a band of iron. A piece of thick paper is then placed between the ring and the follower, and the ring is turned in a lathe to the diameter of the cylinder bore. The ring is thus (while under tension) a circle corresponding to that of the cylinder bore.

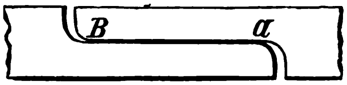


Fig. 6.

The Follower of a piston, is a plate or cover that is employed to hold the piston-rings in place, and the piston-rings should be so fitted that the follower can be bolted firmly up, or otherwise the bolts may come loose and work out, and getting between the piston and the cylinder cover, may cause the piston to knock the cylinder cover out.

Piston Followers are necessary when the rings are set out by springs or other parts adjustable within the piston head. Fig. 7 shows a piston head constructed as follows:

H is the piston head, the webbed portion at the back being termed the *spider*. Between the piston-head H and the follower F, is a broad ring, which is split through at one place so as to permit it to spring out and press the two piston-rings R R against the bore of the cylinder. The inner ring is expanded by the springs S, whose stems fit into the spider. These stems may be simply forced in, or may be set out by screws threaded through the spider at *r*, and having jamb nuts to secure them in their adjusted positions. The follower is bolted to the piston-head by bolts B, whose heads pass in T slots provided in the spider, so that the bolts may be readily removed from the piston-head.

If Water Accumulates in a piston-head, the admission of live steam will vaporize it, and thus produce a pressure which will force the rings out so tight, as to cause them to wear rapidly.

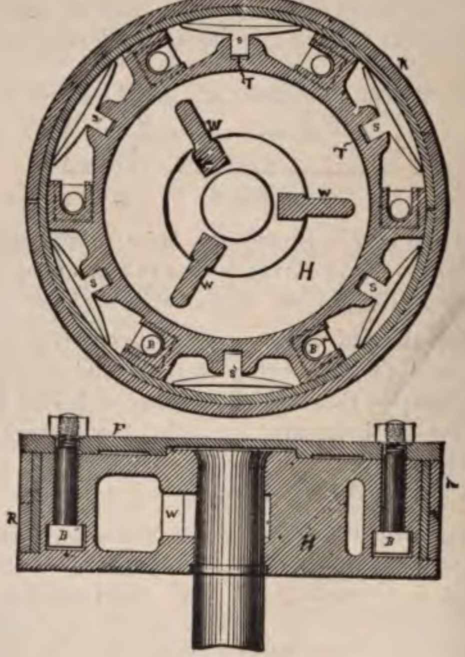


Fig. 7.

The Split of the inner ring *b*, is placed opposite to the splits of the piston-ring, so as to cause the rings to be expanded as evenly around the bore as possible. In other forms, small *S* shaped springs are inserted between the inner

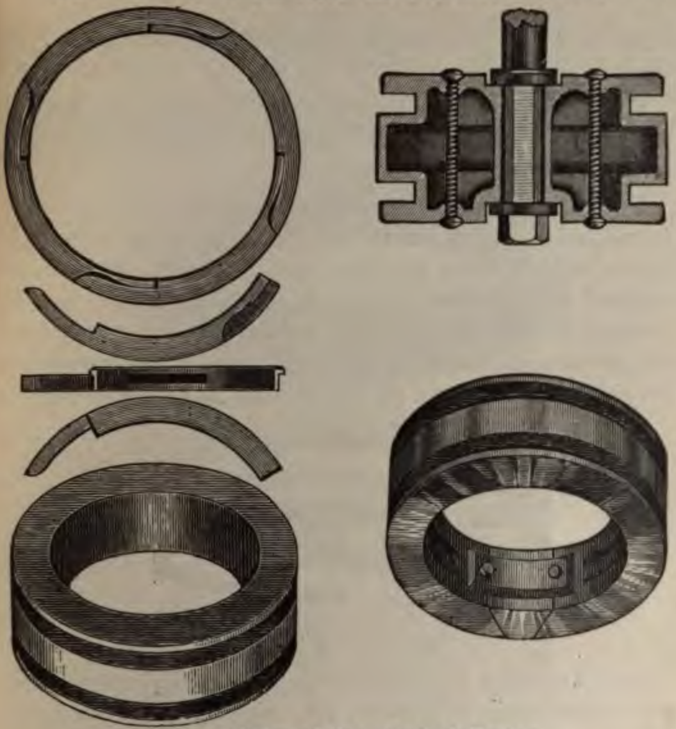


Fig. 8. **Piston of the wheelock Engine.**

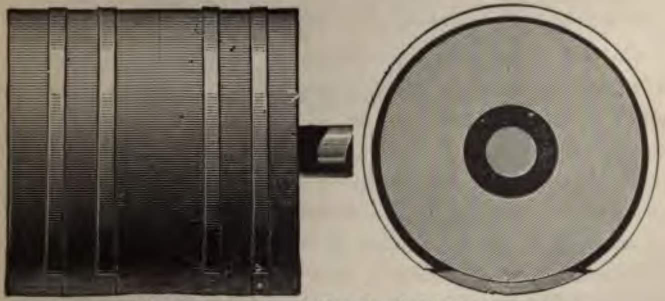


Fig. 9. **Piston of the Straight-Line Engine.**

rings and the piston-rings, being placed close together all around the ring.

Spiral Springs for setting out piston-rings, are applied as in Fig. 8. A long spiral spring is bent into a circle and forced into place in the rings.

The Straight Spring, when bent into a circle and forced into the rings, has two actions on the rings, both tending to enlarge them, viz.: the spring tends to recover its original diameter, and further, to straighten. The vertical pressure against the junk-ring is thus obtained, as well as the pressure against the cylinder, the rings being grooved to the circle of the spring for the purpose, as shown in Fig. 9.

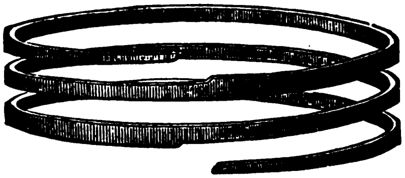


Fig. 10.

In this case the fit of the piston to the cylinder bore does not depend on the fit between the junk-ring and piston body; it may even be $\frac{1}{16}$ inch out of truth, and the only effect will be for the piston-rings to still fill the cylinder, and the springs to be compressed diametrally, as seen in Fig. 9.

Coiled Piston-rings (Fig. 10) are sprung into place after the manner of snap piston-rings. In some cases the end coils are thinned, and let into the neighboring coil, as in the figure, so as to fit into a groove of parallel width in the piston-head, and in others, the coil is of parallel width throughout, and the groove is cut to suit the varying width of the coil. The advantage of this kind of packing is, that the elasticity of the ring is very even throughout the whole circumference, and is not apt to be excessive.

The Babbitt and Harris piston is shown in Fig. 11, at 1 the piston is shown put together, with a piece of the follower shown broken out to show the construction. At 2, the chunk-ring is shown removed, and at 3, a section of the piston-ring is shown. The chunk-ring has hubs, recessed to receive the German silver spiral springs, which set the ring out to the cylinder bore. The rings are an easy fit in the groove in the chunk-ring, so they can move from side to side in the groove, as the steam pressure alternates from one side

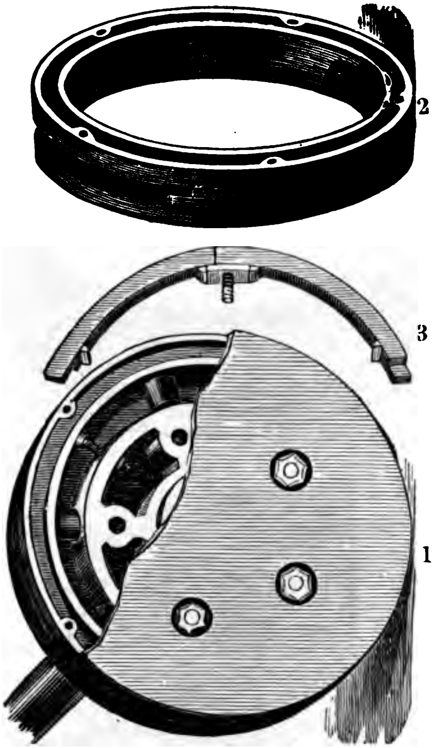
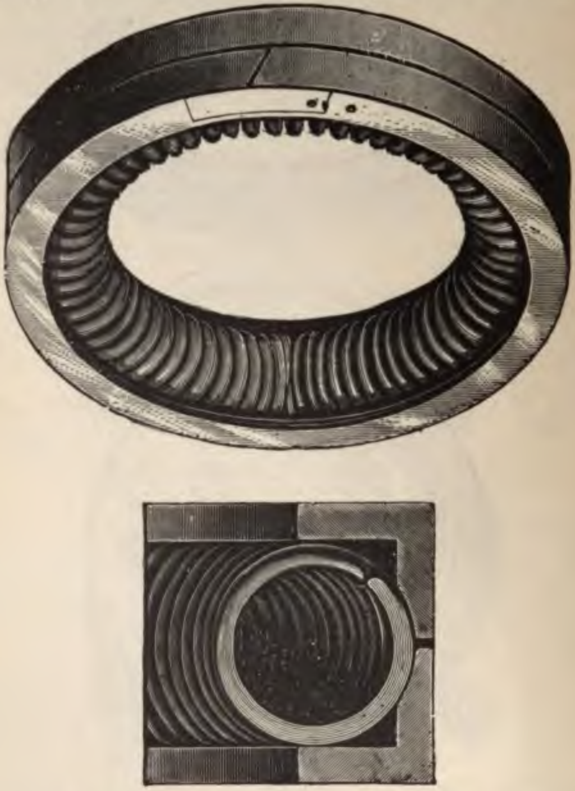


Fig. 11.

to the other of the ring. The steam thus passes down between one side of the ring, and of the groove, and beneath the ring.

The spider, as the webs of the piston-head are termed, fits easily to the hubs on the chunk-ring, which is held central to the cylinder-bore by set screws, threaded through the annular flange of the spider, and set against the bore of the chunk-ring.



Piston with Spiral Spring Packing.

The Effectiveness of a piston-ring may be tested, when the construction of the engine will permit it, by disconnecting the valve for the head-end, setting it so that it covers the port, and then taking off the cylinder cover at the head-end and admitting steam through the crank-end steam port, when any leak in the piston-rings will be seen by the escape of the steam.

THE PISTON-ROD.

Piston-Rods should be of slightly diminishing diameter at the ends, so that the wear shall not leave a shoulder at each end of the rod.

In Determining the diameter of a piston-rod, allowance is made for turning it occasionally in the lathe, to restore its paralellism, the wear reducing its diameter more in the middle than at the ends. The diameter of a piston-rod is found in practice to range between $\frac{1}{6}$ and $\frac{1}{10}$ the diameter of the cylinder bore.

Steel Piston-Rods wear better than those of wrought-iron, being free from scaly seams which are apt to cut the packing and cause the rod to wear in grooves.

The Best method of securing a piston-rod to a piston-head and to the cross-head, is by a taper seat and a key, so that no nut is needed, and the cylinder cover need not have a recess to receive the nut when the piston is at the end of the stroke, and the amount of clearance is correspondingly reduced.

Piston-Head Key-ways are sometimes given so little clearance that the key completely fills the key-way when driven fully home. This prevents the edges of the keys from bulging into the clearance space in the key-way, which action is apt to cause the key to loosen, in time. The key should have a safety-pin at its small end.

When Piston-Rods are threaded into the cross-head, or into the piston, the threads are made an easy fit, and taper seats or split hubs secured by clamping screws, are relied upon to keep the rod true to the cross-head or piston, it being found that the screw alone cannot be relied upon for this purpose.

PISTON-ROD PACKING.

Piston-Rod Packing of fibrous, or similar material, should be cut in rings that will not quite fully envelope the piston-rod, and the first ring should be placed with its split upwards. After two or three rings have been inserted, each having its split at a different part of the bore so as to "break joints", the gland should be screwed up enough to carry the packing home to the back of the stuffing-box This process should be continued until the stuffing-box is filled for about two-thirds of its depth, when the gland may be screwed home.

The Gland should be screwed up quite evenly, so that the packing in the stuffing-box shall be compressed equally all around the rod, and will not cause the gland to bind on the rod or in the stuffing-box bore.

The wrench should be applied first to one nut, giving it a turn or two, and then to the other, and after the gland is firmly home the nuts should be eased back about two turns.

When a gland requires packing, it is proper to take out all the old packing that has become hard and set.

A Leak in piston-rod packing may sometimes be remedied by taking out three or four rings of the packing and reversing it.

If the packing is tightened up while the engine is running, it should be done very gently and evenly, as a very little screwing up may stop the leak, while excessive screwing produces undue friction.

New Glands, for old piston-rods should be made an easy fit to the stuffing-box bore.

The Packing should be of such a size that it may be passed between the rod and the bore of the stuffing-box by finger pressure.

Square Packing, or oval packing is better than round packing, because it takes less pressure to make it fill the stuffing-box.

THE CROSS-HEAD.

In Engines having Corliss Frames, the cross-head is provided with shoes and adjusting screws, to take up the wear.

When guide-bars are shaped thus, _|‾ the cross-head is provided with gibs (usually of brass composition) to take up the wear.

In either case care must be taken to make the adjustment correct, and thus keep the piston-rod in line. The shoes or gibs, should not bear hard upon the guides, but be an easy sliding fit without lost motion.

Cross-Head Pins should be kept eased away on the two parts of their circumference which are within the connecting-rod brasses or boxes, and near the joint faces of the same. This is necessary because the wear is greatest on the crowns of the boxes, and the pins are apt to wear oval. In some engines, the above surface of the pin is cut away, but if it is not, and the pin can be revolved in the cross-head, it is a good plan to give it half a turn occasionally, which will keep it round.

THE GUIDE-BARS.

The Guide-Bars of an engine require to be set exactly in line with the axis of the cylinder bore, so that they may guide the piston to travel in a straight line. They should be an easy sliding fit to the cross-head guide.

The top bar is more difficult to lubricate than the bottom one, especially when it receives the most pressure, as is the case when the top of the fly-wheel runs towards the cylinder.

Cast Iron guide-bars wear better than either brass, iron, or steel ones, so long as they are properly lubricated. The face of each guide-bar should be cut away, so that the ends of the cross-head guides will travel past it. This will prevent a shoulder forming at the ends of the bar as the face wears away. Such shoulders are apt to cause a knock as the connecting-rods are lined up, because in the lining, the connecting-rod is restored to its original length, and the path of the cross-head guides along the bars may be altered.

THE CONNECTING-ROD.

There are two principal kinds of connecting-rods the "strap ended" and the "solid ended." The solid ended wear the best, but are more difficult to get on and off the engine.

Connecting-Rod Straps are secured to the stub ends (as the ends of the rod are called) either by bolts, or by one or two gibs, and the brasses are set up by a taper key or wedge.

The taper for connecting-rod keys is about an inch per foot.

The Angularity of a Connecting-Rod is a term that applies to its path of motion, which is (during all parts of the stroke except on the dead center) at an angle to the line of engine centers. The effect of this angularity is to cause piston motion to be accelerated at one part of the stroke, and retarded at another, thus causing the point of cut-off to occur at different points of the two strokes.

The Direction of the Variation is to cause the point of cut-off to occur later on the stroke when the piston is moving from the head-end of the cylinder towards the crank.

The Amount of Variation caused in the two points of cut-off by the connecting-rod, depends upon the proportion that exists between the length of the crank, and that of the connecting-rod, and is less in proportion as the length of the connecting-rod is greater than that of the crank.

An ordinary length of connecting-rod is six times the length of the crank, or *six cranks* as it is commonly termed.

Fig. 12 represents a piston, connecting-rod and crank, the latter being at half throw, and the rod being twice the length of the piston-stroke.

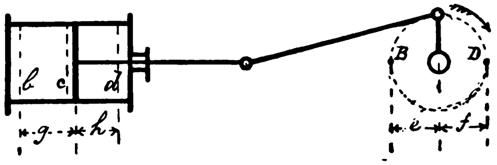


Fig. 12.

The center of the cylinder is at *c*, and the ends of the stroke at *b d*, and it is seen that while the crank has moved from B to half throw, the piston has moved past *c*, or the distance *g*, which is greater than the distance *e*,. During the next quarter-revolution of the crank, the piston will move distance *h*, and the crank distance *f*, hence the piston will move faster at the head than at the crank-end of the cylinder.

THE CRANK.

The Term "Crank" is applied promiscuously to the arms or discs that hold the crank-pin, and the shaft to which it is fixed, is termed the crank-shaft, or sometimes, the driving shaft, of the engine.

A single crank is one in which the crank-pin is held at one end, of which one is between the eccentric and the crank, and the other at the out-board end of the shaft.

The Out-board Bearing is that farthest from the crank-pin.

A Center Crank is one having a bearing on each side of the crank throw or crank discs.

A solid center crank is sometimes termed a *return* crank, which distinguishes it from a single crank, or two crank discs, connected by the crank-pin.

Single cranks are employed upon the slower running engines, or else have *bobs* or overhanging pieces to counterbalance them, and the weight of the reciprocating parts, which consist of the connecting-rod, cross-head, piston-rod and piston.

For fast running engines, crank discs (or circular plates) are generally preferred, the counter-balancing weight being given by thickening the part opposite to the crank-pin.

The Bores of cranks are either made parallel or else given a very slight taper, as $\frac{1}{16}$ of an inch per foot of length.

Cranks are usually secured to the shaft by a steel key, whether the crank is shrunk on, or put on by hydraulic pressure.

The method of shrinking a crank is to make its bore smaller in diameter than the diameter of its seat on the crank-shaft, to an amount of about $\frac{1}{64}$ of an inch per foot of diameter. The crank is then heated to about 600,° or nearly red hot, which expands the bore and permits of the crank being put on the shaft. In cooling, the crank-bore shrinks and grips the shaft.

Shrinking a crank is liable to throw the axis of the crank-pin out of parallel with the axis of the crank-shaft, unless care is taken to heat the crank evenly.

Crank-Pins are sometimes made taper, and secured in the crank by a taper key; in other practice they are secured by a nut, but the best method is to either put them in by hydraulic pressure, or shrink them in.

When a crank-pin is to be shrunk in its seat, the crank may be made parallel. If it is to be put in by hydraulic pressure, a taper of not more than $\frac{1}{16}$ of an inch per foot, may be employed with advantage, while if it is to be keyed the taper may be made about $\frac{1}{4}$ inch per foot.

Crank-pins should be made of steel, which is less likely to cut or heat than wrought iron.

Cutting is the term applied to an abrading action, that occurs upon moving surfaces when the parts fit too tight; the lubrication is imperfect, or the pressure per square inch on the bearing area is too great.

A Journal is a cylindrical part of a shaft or rod, that acts as a pivot and supports another piece, and to guide its path of motion.

Crank-pins are sometimes termed wrist-pins, but this is a misnomer, since the term wrist-pin distinguishes a similar pin when not used in connection with a crank.

THE FLY-WHEEL.

A Fly-Wheel acts as a reservoir of power and equalizer of motion, storing up, during the live steam period, a certain amount of power, which it gives back to the crank-shaft during the remainder of the stroke, and thus equalizes the speed.

From a paper read before the American Society of Mechanical Engineer's, by William Johnson, the following is taken:

The weight of a fly-wheel is equal to the continued product of the area of the piston in square inches; boiler pressure by gauge in pounds; stroke of engine in feet; value for cut-off; coefficient of fluctuation, and accelerated force of gravity, divided by the square of the velocity in feet per second of the center of gyration of the wheel.

The value for cut-off, as given by Professor Robinson, may be taken as ranging from 0.16 to 0.22, and the coefficient of fluctuation at from 20 to 60, according to the degree of regulation required. One example will serve as an illustration.

Take an engine with a cylinder 18″×36″; pressure, 80 pounds; cut-off at half stroke; fluctuation, 40; diameter of wheel, 10 feet; number of revolutions, 100; and assuming the center of gyration at a distance from center of wheel of four-fifths the radius. Avoiding fractions we have,

$$\frac{254 \times 80 \times 3 \times 0.18 \times 40 \times 32}{1754} = 8{,}000 \text{ pounds}$$

weight of wheel,

Take the same 'example, but with half the number of revolutions, and we have as our divisor $\frac{1754}{4} = 438\frac{1}{2}$, and the weight of wheel 32,000 pounds.

Again, take the same example, but increase the speed to 150 revolutions, and the divisor becomes $1764 \times 2.25 = 3946$ or 3550 pounds, as the weight of wheel. If now we take the same example, but change the coefficient to 20, we shall find the weight of wheel reduced one-half, from which we learn that, while the weight is inversely as the square of the velocity, it is directly as the coefficient of fluctuation.

In conclusion, it will be seen from the example that the regulating power for the weights determined remains constant with a given fluctuation, without regard to the time in which the fluctuation occurs."

The following from the pen of Professor Robinson is given as explanatory of the above rule.

It is usually supposed by those who have the mathematical solution of the problem of the fly-wheel of steam engines, that the regulating power varies as the square of the velocity of the rim of wheel. This is because the mathematical expression, giving relation between velocity and fluctuation, seems to require the former to be squared when the latter is at the first power, But the relation these two quantities will be found to be affected by the conditions of other things. For instance, the velocities will require to be cubed in some comparisons, squared in others, simply proportioned in others, and even constant in others.

But before going to figures, let us notice what specific meaning should apply to terms to be used. Speed, for instance, may be used in the sense of number of revolutions per second, velocity fly-wheel may be taken for velocity in feet per second of the rim of wheel along the path, or circle of the rim. Fluctuation of speed may be used in a general sense to mean irregularity. But coefficient of fluctuation of speed may be used in a general sense to mean irregularity.

But coefficient of fluctuation has a definite meaning, as follows:

It is the number obtained by dividing the difference between the greatest and least number of revolutions per second, occuring in a certain cycle of changes, by the average number. In case of the fly-wheel of an engine, for instance, we have a series of changes of velocity or speed occuring within one revolution. If a whole revolution and no more is required for effecting all the varieties of change in volocity which occur, then this series of changes is the cycle above named. If the whole range in variety occurs in a half-revolution, the same, exactly, being repeated in the other half-revolution, then this half-revolution makes the cycle. This would be the case in an engine with an exactly equalized valve-gear, where the crank-pin runs in a block, the latter sliding in a transverse straight slot in the cross-head. In this cycle of fluctuation there will, of course, be some point where the velocity of rim is greatest, and another where it is least. To illustrate: Suppose that where it is greatest the velocity of a prick-punch mark on the rim be such that, if just this velocity could be maintained constant for one second it would move 12 feet. Suppose likewise that where it is least the velocity would be 9 feet. Then the range of fluctuation is from 12 to 9, and from 9 to 12. Suppose, again, that in one minute the point moves, altogether, 600 feet, including fast and slow, the fluctuation during that time being in exact repetition, then in one second the average movement will be 10 feet. The *coefficient* of fluctuation will then be $\frac{12-9}{10}=0.3$.

This coefficient of fluctuation is an important factor in estimating fly-wheels. It serves to rationalize our notions about fly-wheels, and its use is well authorized both as a name of a tangible conception, and as capable of numerical expression.

The numerical value of the coefficient snould be, as given by some authors, from a fortieth to a sixtieth, for the most perfect regulation, such as in factories of textile fabrics; while for ordinary uses it may be as low as a thirtieth, or even a twentieth. Suppose the latter value be taken, or $\frac{1}{20}=0.05$. The meaning is that in that part of the revolution where the velocity is greatest, it is one in twenty faster than where it is slowest. It applies to the speed as well as the feet per second. That is: In that part of the revolution where the wheel moves fastest, its speed for an instant is at the rate of one revolution in twenty faster than where it moves slowest; suppose a wheel runs at a speed of 120 revolutions per minute: The fluctuation might be then from 118 to 124 within a single revolution, the coefficient of fluctuation being

$$\frac{124-118}{120}=\frac{1}{20},$$ as stated.

The difference in the fluctuation for high and low speed engines, equally well regulated, is not a difference numerically, but simply in the period of time within which the fluctuation occurs. Thus suppose for illustration, that an engine works 40 revolutions per minute with a fluctuation in each revolution from a rate of 39 to 41.

Then

$$\frac{41-39}{40}=\frac{2}{40}=\frac{1}{20}$$

the same as before. But here the time taken for making the change, is three times as great as in the previous example. The coefficient of fluctuation then has no reference to the time the change of velocity is confined to, but is dependent entirely upon change of rate of speed.

Consider for a moment, a buzz saw driven by either of the above engines, the saw giving forth a musical tone varying in pitch with the speed. Neglect the balance-wheel, effect of the pulleys, shafting, etc., between the saw and engine, the saw being regarded as varying in velocity exactly in proportion to the fly-wheel. Then the change of pitch of musical note with either engine will be the same. The rapidity with which the changes occur, will however, be in accordance with the speeds of engines.

The coefficient of fluctuation may therefore be taken as a sort of unit, by means of which we may make an intelligent comparison of the action of fly-wheels in different cases. To establish a rule for comparing, which will incorporate this coefficient, we have to consider that the work developed by the engine in a half-revolution, varies from nothing at the dead centers to a maximum near the mid stroke, while the resistance overcome is constant, and for a stroke equal in amount. This supposes the work of each stroke to be equal. Hence, near the mid stroke, the work applied will be in excess, while near the ends it will be in deficiency. The retardation during a deficiency will be equal to the acceleration during an excess. At the beginning of an excess the velocity will be least, while at the end it will be greatest. The excess of work between these points must therefore exactly account for the increase of speed. This brings the question down to where we can compare it with familiar examples of motion resulting from the action of force.

Gravity developes 100 ft. lbs. of work when 10 lbs. falls 10 ft., and if a number of experiments be made with different weights and heights, it would be found that the foot lbs. of work in each case would be equal to the product of the square of the velocity, by half the mass, the mass being equal to the weight divided by about 32.2. In comparing two different falls of the same weight, it will be found that the difference in foot lbs. is equal to the difference in products.

Similarly in the fly-wheel, the foot lbs. of work in an excess is equal to the difference in the squares of the velocity of rim, by half its mass. Now because the difference of the squares of the velocity is equal to the simple difference multiplied by the sum, the quantity last named above can be said to be equal to the mass multiplied by the square of the average velocity, and multiplied by the quotient of the difference of velocity, divided by the average velocity. The last named quotient is seen to be the coefficient of fluctuation. Hence, rule for fly-wheels. An excess in foot pounds is equal to the continued product of the mass of rim, the square of average velocity of rim, and the coefficient of flucuation. The mass of the rim equals its net, divided by 32.2. The velocity is the number of feet the rim moves per second. To find the excess, multiply the work of one stroke in foot pounds by proper value in following table:

Pressure of steam—6 atmospheres.

Cut-Off	.3	.5	.7	1.0 of stroke.
Value	.16	.18	.19	.17
Condensing Engines.				
Value	.18	.21	.22	.21

Example 1—Take an engine with cylinder 10×20 inches making 100 revolutions per minute. Coefficient of fluctu-

ation $=\frac{1}{30}$, cutting off steam at half-stroke. Pressure of steam in steam chest, 6 atmospheres or 85 pounds per square inch by steam gauge. Diameter of rim, 6 feet.

The area of piston is 78 square inches. Total initial pressure on piston 6630 pounds. Foot pounds per stroke $= 6630 \text{x} \frac{20}{12} = 11050.$ Excess for half-stroke cut-off $=.18 \times 11050. = 1989.$ foot pounds.

The velocity of rim is $3\frac{1}{7} \times 6 \times 100$ feet per minute, or 31.4 feet per second. Hence by rule

$$1989 = \frac{\text{wt.}}{32.2} \times 31.4 \times 31.4 \times \frac{1}{30};$$

whence the weight of fly-wheel=2029 pounds.

Though the correct value of the foot pounds per stroke is actually less for expansion engines than the product of initial pressure by stroke, still the greater convenience of this value has led to its being retained for use in the above table, the latter having been adapted to it. The table is given for the purpose of facilitating the determination of the excess.

THE SLIDE-VALVE.

The Various Events which are governed by the slide-valve of a steam engine, are as follows:

The Live Steam Period is that during which the steam is admitted from the steam-chest into the cylinder and the steam admitted during this period is termed *live* steam.

The Point of Cut-off is that at which the valve closes the steam port, and the admission of steam into the cylinder is stopped, hence the point of cut-off is at the end of the live steam period.

The Period of Expansion is that during which the steam is allowed to expand in the cylinder, and therefore begins at the point of cut-off, and ends at the point of release.

The Point of Release is that at which the valve opens the port and permits the steam to escape.

The Point of Compression is that at which the exhaust port is closed, which occurs before the piston has reached the end of its stroke; the steam that has not passed out of the cylinder is therefore compressed, the compression continuing until the valve opens for the lead.

The Lead of the Valve is the amount the port is open to the live steam, when the crank is on the dead center.

The Point of Admission is that at which the port opens for the live steam to enter, and it follows, that the lead and compression both act as a cushion, arresting the motion of the piston when it reaches the end of the stroke.

Cushioning begins, however, at the time the exhaust port is closed enough to arrest the escape of the steam, while compression begins when the valve has closed the exhaust port.

THE PLAIN SLIDE-VALVE OR D VALVE.

The construction of a common slide-valve is shown in Fig. 13, in which the valve is shown in its mid-position, P P

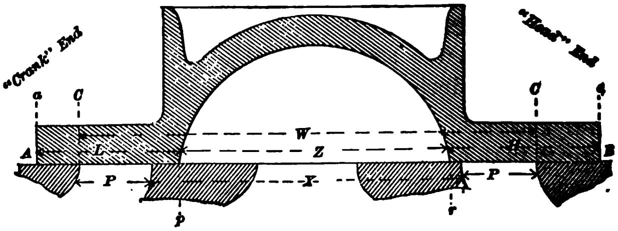


Fig. 13.

are the cylinder steam ports (as the openings through which the steam passes from the steam-chest to the cylinder, are termed), and at X is the cylinder exhaust port, through which the steam escapes from the cylinder. Z is the valve exhaust port or exhaust cavity.

The Lip of a valve is the width of its flange face or the distance L, which is measured from the steam edge A, to the exhaust cavity Z. At the other end of the valve, H is the lip extending from the steam edge B to the exhaust cavity.

Steam Lap is the distance the steam ends (or the steam edges as they are called) A B, overlap the steam ports, this distance being shown on the ends of the valve at *a* C. If the valve had no steam lap, its steam edges would just cover the ports, as denoted by the dimension W.

Exhaust Lap is the amount the exhaust cavity Z overlaps the bridges *q* *r*.

Unequal steam Lap is given to cause the point of cut-off to occur at equal points in the piston-stroke, thus in the figure there is more steam lap at the head-end than at the crank-end of the valve. But unequal lap could also be given in order to greatly vary the points of cut-off for the two piston-strokes, if such was desired.

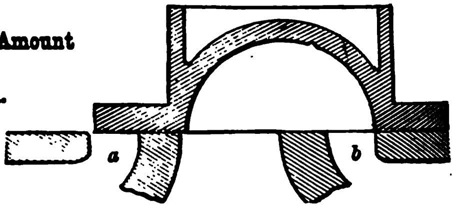
Unequal Exhaust Lap may be given to equalize the potnt of release, or to equalize the points of compression.

The Head-End of the valve (or of the cylinder), is that which is furthest from the crank-shaft, the other end, or that nearest to the crank-shaft, being termed the crank-end.

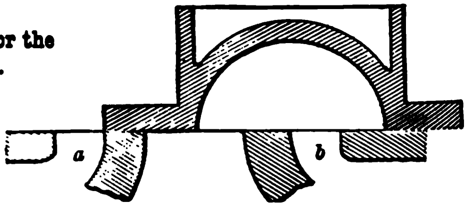
THE ACTION OF A COMMON SLIDE-VALVE.

The Action of a common slide-valve may be traced as follows.

Port a, Open to the Amount of The Lead.



Port a, Full Open for the Admission.



Port a, Closed for Cut-off.

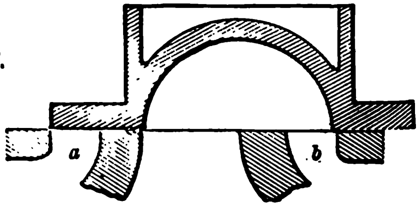
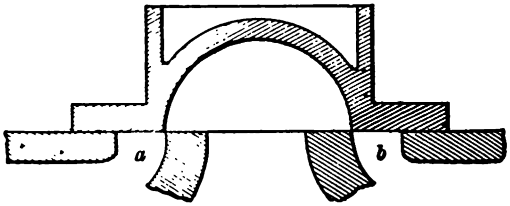


Fig. 14.

Valve Opening Port a, for the Exhuast.



Port a, Full Open for the Exhaust.

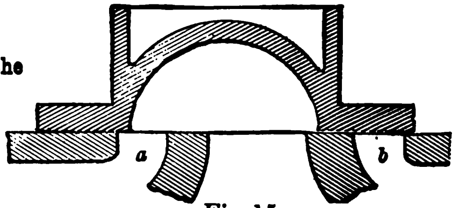


Fig. 15.

Suppose the port *a* to be at the head-end of the cylinder and open to the amount of the lead with the crank on the corresponding dead center, and if the valve travel be made equal to twice the lap and the lead, the various positions of the valve will be as marked in Figs. 14 and 15; the event corresponding to each valve position being stated in the figures.

DOUBLE PORTED VALVES.

The Term *Port* applies strictly to the area of opening of the steam passage, where it emerges upon the valve seat. The term *steam passage* includes the full length of the opening from the cylinder-bore to the face upon which the valve is seated.

A Double Ported Steam Port is one in which there are *two* openings or steam ports, leading into *one steam passage.*

A Double Ported Valve is one in which there are two ports *at each end* of the valve. These two ports, in some cases, admit steam to a single cylinder port, and in others to two steam ports, terminating in one steam passage.

A Griddle Valve is one that has two or more ports at each end, upon a seat that has two or more ports for each steam passage.

Double ported valves are employed in some cases, to increase the admission of live steam to the cylinder, and in others to increase the exhaust openings also. The effectiveness of a double ported valve is mainly valuable at the beginning of the stroke, and is especially valuable in cases when the travel of the valve is diminished to hasten the point of cut-off, because in such cases, the outer edges of the valve do not open the steam port to its full width, and a single port is apt to wire-draw the steam, being sometimes applied to those having two ports, but usually to those having more than two. By the employment of more than one port, or several ports, a sufficient admission may be obtained with less valve travel. Fig. 16 is a plan of the valve used in the Porter Allen Engine, *a* represents the steam port, and *m* a plate that is adjusted to fit to the back of the valve so as to exclude the steam, which enters from the ends in four streams, as shown by the arrows, the valve is therefore in effect, four ported, while the steam port is single ported.

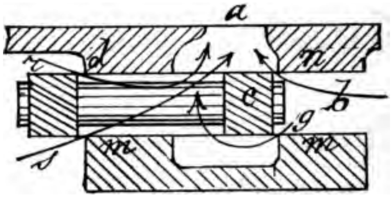


Fig. 16.

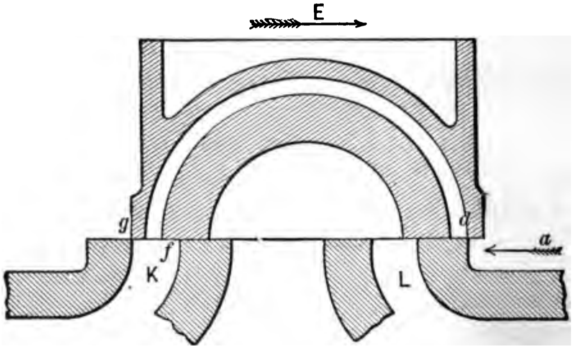


Fig. 17.

The Allen Double Ported Valve is one in which the second port increases the port opening for the admission only, as shown in Fig. 17, in which the valve is moving in the direction of the arrow E, the port K will receive steam through the opening at *g*, and from port *d*, steam entering it is shown by the arrow *a*. The second port forms part of the lap of the valve, and enables the travel to be short enough to cut off at early points in the stroke, without employing so much steam lap as to widely distort the points of cut-off, this latter being a defect of the D valve. ·

Webb's Patent slide-valve is circular, and is so arranged as to be free to revolve in the hoop of the valve rod, the effect being that the valve moves around, or to and fro in the hoop, without any special mechanism to produce such movement, and the result is, that the valve and port facings wear smooth and even without any tendency to become grooved.

BALANCED VALVES.

A Balanced Valve is one in which means are employed to relieve the back of the valve of the steam pressure, and thus prevent its being forced to its seat with unnecessary pressure.

In some of the most successful balanced valves, this is accomplished by providing a cover-plate, which may be set up to exclude the steam from the back of the valve which works (a sliding fit) between the valve face and the face of the cover-plate. Such a method of balancing is sufficiently effective for all practical purposes, if the following conditions are observed: The valve rod must be accurately guided so as to avoid side strains; the valve must fit accurately to its seat and to the cover-plate, and the adjustment so made that the valve slides freely at first, being steam tight, and yet allowing room for lubrication to enter. When the travel of a valve, balanced by a cover-plate, is varied to alter the point of cut-off, the construction must be such that the ends of the valve, at the shortest stroke, pass over the ends of the seat and cover-plate faces, or otherwise the middle of the seat and cover-plate faces will wear hollow.

The Buckeye, Porter-Allen, and Straight-Line Engines are examples of practically balanced valves. The first of these has a balancing device that follows up the wear; the second has an adjustment, whereby the cover-plate may be set up to take up the wear; and in the third the wear is reduced to a minimum, by accurately fitting and guiding the parts.

The construction of the valve in the Straight-Line Engine is shown in Fig. 18, in which B represents the cylinder-bore;

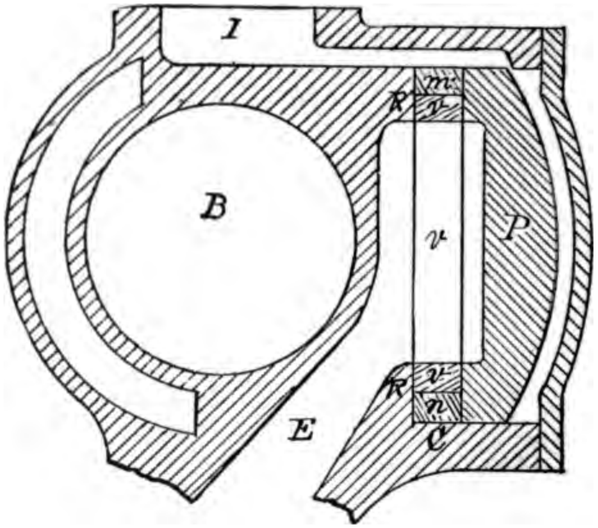


Fig. 18

the valve *v* rests on a parallel strip *n*, and on its top rests the parallel strip *m*, the pressure relieving plate P is set up firmly against the pieces *m n*, whose thicknesses are such as to leave the valve a working fit between the faces of R R and of P.

PISTON-VALVES.

Piston-Valves are cylindrical, and of the general form shown in Fig. 19, *v* representing the valve. In the figure the valve is shown operating for two sets of ports, *a b* being for one cylinder, and *c d* for the other.

Referring first to the ports *c d*, the live steam enters at P,

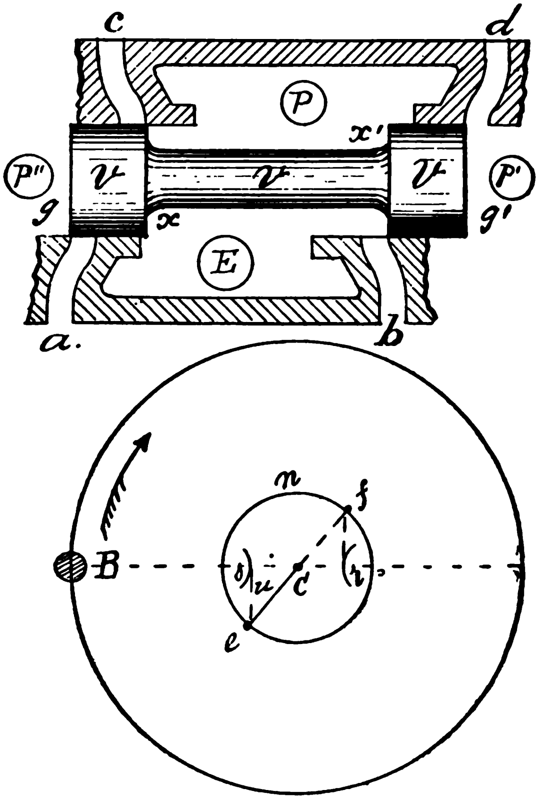


Fig. 19.

and, as the valve moves to the left, the port *c* receives steam, while the exhaust for port *d* is fully opened, hence the valve takes steam in the middle, and exhausts it at the ends. The edges *x x'*, therefore, in this case, effect the admission and cut-off, and the ends $g\,g'$, the admission and compression.

For ports a and b the steam enters at P and P′, and exhausts through E, hence the edges $g\ g'$ effect the admission and cut-off, and the ends x and x' effect the exhaust and compression, the exhaust finding exit through a pipe as at E.

When Steam enters in the middle of the valve, the valve is balanced, because it envelopes the valve all around its circumference. But when the steam enters at the ends of the valve and exhaust in the middle, the valve steam excludes the steam pressure at one end, and in order to balance the valve, the area at the head-end of the valve must equal that at the crank, or valve rod end, which may be accomplished by increasing its diameter.

The Eccentric Position for a piston-valve taking steam in the middle, is opposite to that required when the steam is admitted at the ends. Suppose, for example, that in Fig. 19 the outer circle represents the path of the crank-pin, and the circle n, the path of the eccentric center, and supposing the valve to be sufficient to open the port C fully as a steam port, we mark from the point of intersection of circle n, with the line of centers (shown dotted), and with the width of the port as a radius, an arc s. From s, we mark a line u, and a line drawn from C to the end of u, gives at e, the position of the eccentric center when the crank is on the dead center at B, the eccentric throw-line being represented by the line from C to e. In this case the valve moves to the left, in order to open the port C. Now suppose the port a is to receive steam, the crank being at B, and the steam being admitted by the end g of the valve, the latter must move to the right, and to find the eccentric position, the width of the port is taken, and from the circle m on the line of centers an arc r is marked, and a line from r gives at f the position of the eccentric center, and it is seen that f is exactly opposite to e, leading or being in advance of the crank instead of following it in the path of revolution of the engine.

The Action of a Piston-Valve is precisely the same as that of a common slide-valve, having the same amount of lap and travel. The lap of a piston-valve is the thickness of the head, as in Fig. 20. To take up the wear of piston-valves, and prevent them from leaking, two means are taken; the first is to provide bushings for them to work in, and provide new bushings whose bores are sufficiently less in diameter than the old bushings, to restore the fit; the second is to provide the heads of the valve with packing-rings similar to those used for an engine piston, but means must be

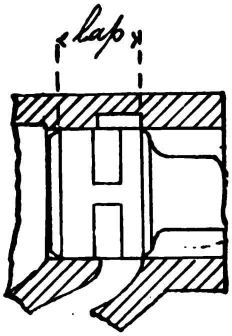


Fig. 20.

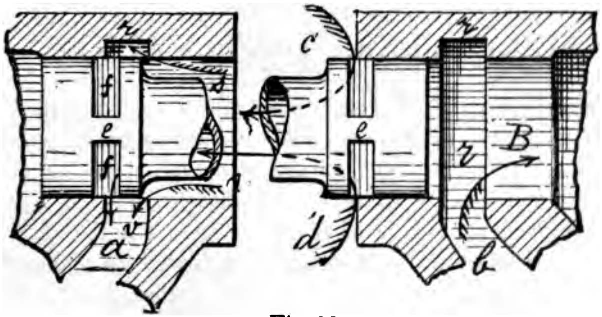


Fig. 21.

taken to prevent these rings from opening when passing over the steam-port. which in some cases, terminates in an annular groove passing all around the valve. When piston-valves vary the point of cut-off, by having their travel varied, the exhaust and the compression occur earlier in the stroke in proportion as the valve travel is reduced and the point of cut-off hastened. Fig. 21 represents the double ported piston-valve, employed on the Armington-Sim's Engine, the steam having two means of ingress to the ports, one through the valve as shown by the arrows *c d* at one end, and the other direct into the port *a*, as shown by the arrows *s* and *v*.

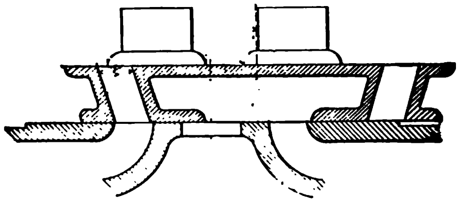


Fig. 22.

SEPARATE CUT-OFF VALVES.

Meyer's Cut-Off Valve is constructed as shown in Fig. 22, M being the main valve, and *v v* the two cut-off valves, whose sole duty is to cut off the steam at an earlier point than the main valve would do. If the engine is to have a fixed point of cut-off, or in other words, it the cut-off is always to occur at some one particular point in the stroke, the valves may be set to do so, and equalize the points of cut-off.

Variable points of cut-off with the Meyer's valve may be obtained by shifting the position of the eccentric that operates the cut-off valve, but it is usually done by means of moving the valve by a right and left hand screw, such as shown in Fig. 23. The cut-off eccentric is set ahead of the main ccentric, so that the cut-off valve will close the ports before he main valve would do so, thus in the figure the cut-off valve s shown to have effected the cut-off for port *a*, by the time

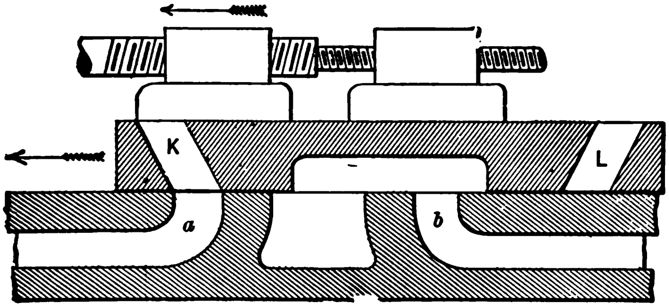


Fig. 23.

the main valve has fully opened port *a*, and is reversing its motion. If the engine requires to reverse its motion the cut-off eccentric is set exactly opposite to the crank, as in Fig.

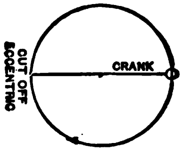


Fig. 24.

24, but otherwise it may be set 8 or 10° either ahead of, or behind the crank, but if set too little ahead of the crank, the port may reopen after the cut-off has been effected.

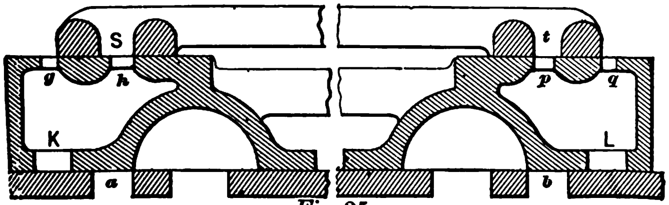


Fig. 25.

Fig. 25 shows a form of cut-off valve, in which the back of the main valve and the cut-off valve being double ported, as shown at *g h* and *p q*. In many cases the main valve is formed as in Fig. 23, but double ported.

Two Separate Valves as shown in the figure, give the same results as a single valve having the same lap and travel.

Gonzenback's cut-off valve is constructed as in Fig. 26,

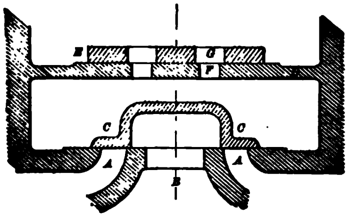


Fig. 26.

the steam-chest having two compartments. A A are the cylinder steam-ports, C the main valve, and E the cut-off valve, whose ports (as G) are made wider than the ports F.

Reducing the Travel delays the point of cut-off in the Gonzenback valve, whereas in the common slide-valve, it gives an earlier cut-off.

THE ECCENTRIC.

When a Single Eccentric is used, it is simply termed *the* eccentric. If a cut-off valve (or two cut-off valves) are used, upon the engine, then the eccentric that works the main valve, is called the main eccentric, while that which works the cut-off valve or valves, is called the cut-off eccentric. The main valve is that which works on the cylinder face; the cut-off valve is that which effects the cut-off.

A Shifting Eccentric is one that is *moved across* the shaft so as to alter its amount of throw, and, therefore, the amount of valve travel, the effect being to vary the point of cut-off.

In engines where a constant amount of lead is given the eccentric should be secured to the crank-shaft by a feather or key, sunk into the crank-shaft so as to prevent the eccentric from moving, while enabling it to be taken off and replaced without requiring any operations to adjust its position with relation to the crank.

The feather should fit tight on the sides, as well as on the top and bottom, and may have a slight taper on the sides, which will make it easier to fit the featherway or keyway, to the feather, and easier to put the eccentric on, or take it off.

By this means the eccentric cannot shift, and may be replaced after being taken off without having to set the whole valve motion over again.

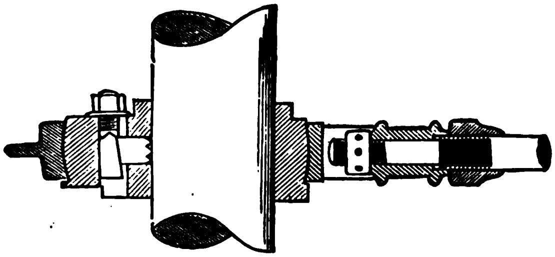


Fig. 27.

When the amount of valve lead or of compression is varied to suit the speed at which the engine is to run, or to aid the counter-balancing of the engine, a feather cannot be used because it will not permit the eccentric to be moved to effect the adjustment.

Set screws possess disadvantages, inasmuch as that the point of the set screw may leave an indention, which, if the eccentric is moved a trifle, may cause the set screw point to fall back into the old indentation, thus rendering it difficult to make a small adjustment of eccentric position.

Fig. 27 shows a simple and effective method employed of [illegible] valve and the [illegible] Engine. [illegible] as shown at *g* [illegible] and *p q*. [illegible] circumference [illegible] formed as in Fig. [illegible] V-edge shown.

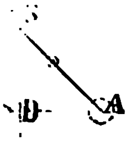
Two Separate Valves [illegible] secure same results as a single [illegible]

Gonzenback's [illegible]

[illegible] GOVERNORS.

[illegible] **[illegible]ciples of Construction** of this class [illegible] as follows: In Fig. 28 let S [illegible] two arms are pivoted at B, these [illegible] lower ends, balls or weights A; from [illegible] to D.

[illegible] rest, the balls A would hang [illegible] D, but as soon as S is revolved [illegible] rotated by the arms and the balls A [illegible] outward, travelling in a path or circle [illegible] diameter until it attains the limit [illegible] arms will permit.



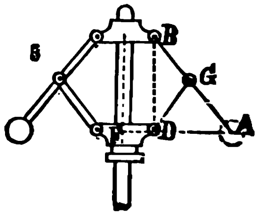


Fig. 29.

[illegible] from the lowest to the high[illegible] balls, the piece D, which is a sliding [illegible] carried by the spindle S.

[illegible] which the balls are revolved [illegible] variation of speed [illegible] of piece D, and an arm from D operates the throttle valve of the governor.

The height of the cone in which the balls swing is the height from D to B, whether the construction be as in the figure, or as in figure 29, these heights being equal in the two figures.

The resistance offered to the rise of the balls in obedience to the centrifugal force, is that of gravity, which tends to keep them downwards, and also the friction of those parts of the governor that are actuated by the rise of the balls, and it is obvious, that in order that the balls may not incline to change their height, the centrifugal force and the forces opposing it, must be equal.

An Isochronal Governor is one in which these two opposing forces are equal throughout the whole range of governor action, or, in other words, equal, let the vertical height of the plane, in which the balls revolve or swing, be what it may.

A Dancing Governor is one that acts spasmodically. Such an action may occur from undue friction in the parts of the governor or of its throttle valve.

The friction offers a greater resistance to starting the parts in motion, than it does to keep them in motion after being started, hence the parts are apt to remain at rest too long, and to move too far after being put in motion.

Rule to find the number of revolutions a governor should make. Divide the constant number 375.36 by twice the square root of the height of the cone in inches. The quotient is the proper number of revolutions per minute.

Example. A governor with arms 30½ inches long, measuring from the center of suspension to the center of the ball, revolves, in the mean position of the arms, at an angle of about 30 degrees with a vertical spindle forming a cone of about 26½ inches high. At what number of revolutions per minute should this governor be driven? Here the height of the cone being 26.5 inches, the square root of which is 5.14 and twice the square root 10.28, we divide 375.36 by 10.28, which gives us 36.5 as the proper number of revolutions per minute at which the governor should be driven.

The Parabolic Governor is isochronous, because the balls swing out in the arc of a parabola which is effected by suspending the ball arms by a ribbon of steel which is secured to the ends of the prongs T; Fig. 30, the face of each prong is a curve, so that as the balls alter their vertical height, the ribbon of metal leaves contact, or takes contact, as the case may be, at a different part of the curve, thus in effect altering the length of the arms, and causing their path, in rising or falling, to be in the arc or path of a parabola.

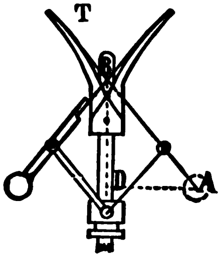


Fig. 30.

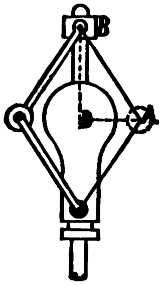


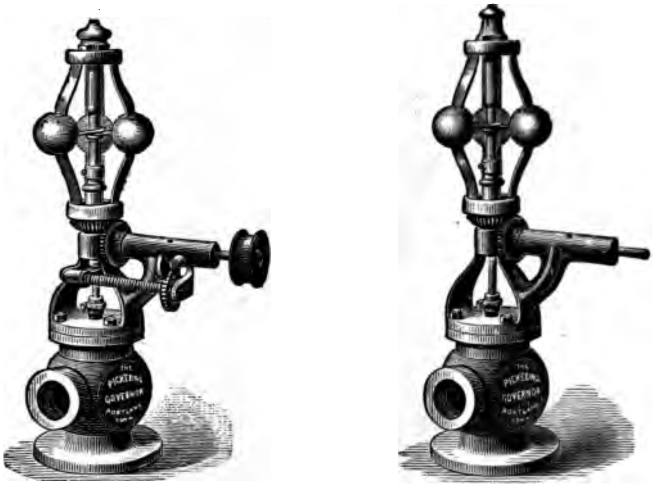
Fig. 31.

In the Porter Governor, whose principles of construction are shown in Fig. 31, the balls are loaded with a central weight D. From the method of suspension, the rise and fall of the weight D is twice that of the ball A. In this class of governor the centrifugal force is generated by the balls A and the links, while the opposing force is the gravity of the parts added to that of the central weight D, hence, a greater amount of centrifugal force must be generated in order to lift the weight D. This enables the governor to run at a higher speed.

THE PICKERING GOVERNOR.

The Construction of the Pickering Governor is as follows:

In Fig. 32 it is shown in its simplest form at A, and at B with the driving pulley and speeder (or engine speed regulating device) attached. This speeder consists of a spiral spring whose tension may be adjusted to more or less resist the rise of the governor balls, and thus enable the engine to run at a greater speed for a given amount of rise of the governor balls, hence by increasing the spring tension the engine speed is increased.



B *Fig.* 32. A

THE SPRING ADJUSTMENT.

The Adjustment of the Spring Tension is made by a worm actuating a worm-wheel on a rod passing through the spring, and to which one end of the spring is attached, the other acting on an arm that projects into a slot in the governor spindle. It is obvious that the speeder can be adjusted while the engine is running.

In Fig. 33 the governor is shown with the speeder, and Sawyer's valve, the latter enabling the governor valve to be opened or closed without affecting the rise and fall of the governor balls, which is done by operating the arm shown on the right, whose ends are provided with loops so that a cord may be attached, enabling the engineer to operate the governor from a distance.

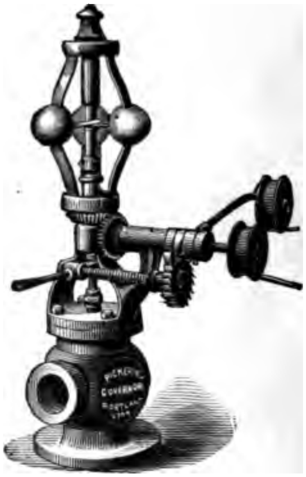
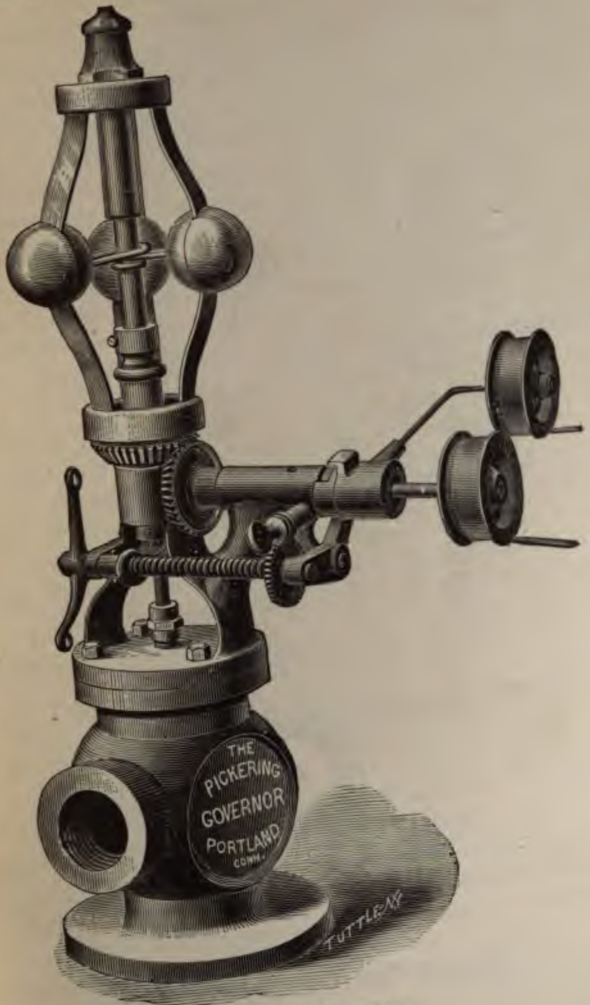


Fig. 33.

The Safety Stop or Stop Motion is shown on the right. It acts to close the governor valve and stop the engine in case the belt that drives the governor should get off the pulley or break. This stop motion consists of a pulley suspended by a rod, and riding on the belt which supports its weight. Should the governor belt break, this pulley falls and severs



The Pickering Governor.

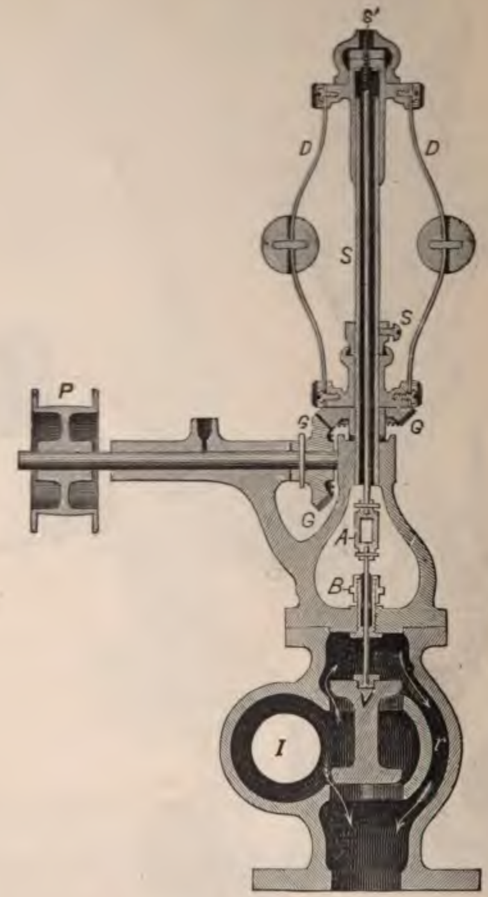


Fig. 33a.

Sectional View of the Pickering Governor.

the connection between the valve and the governor closing the valve, and holding it closed. Fig. 33*a* shows the gover nor in section to expand the construction of the valve. The valve V is what is termed a poppet or poppet valve, which is balanced, because the steam entering at I, and taking the course denoted by the arrows, acts equally on both ends of the valve and does not press it in either direction, while as the steam surrounds the valve it is not pressed sideways.

At B is a gland or stuffing box to keep the spindle or rod steam-tight. At A is the slot for receiving the arm from the speeder and from the stop motion.

P is obviously the driving pulley, imparting motion to the bevil wheels G, which drives the outer spindle S, the inner spindle *s'* being connected to A. The balls are upon ribbon springs D, which are secured at their lower ends to a link fast to the spindle S.

The centripetal force generated by the balls causes them to move outwards, their upper ends pulling down the cap to which they are secured, and this cap operates the valve.

Governors of this class are sometimes termed *fly-ball* governors.

THE WATERS GOVERNOR.

In The Waters Governor the balls are suspended by pivoted links, and curved springs, lying horizontally, are employed to assist the gravity of the balls in creating a centrifugal force. The construction is such that the balls move outwards in a horizontal plane, while the joints of the links are relieved of friction.

A triple ported piston-valve is employed, thus giving a wide variation of steam opening for a given amount of vertical motion of the valve.

The Bookwalter Engine is shown in figs. 34 and 35.

The first is a vertical engine, the frame being bolted to the boiler.

The horizontal engine, Fig. 35, has a center crank, the steam-chest being set at an angle. The boiler is mounted on skids, and requires no foundation. Fig. 36 shows a horizontal center crank engine with feed water heater attached. The boiler-feed pump is here worked from the cross-head.

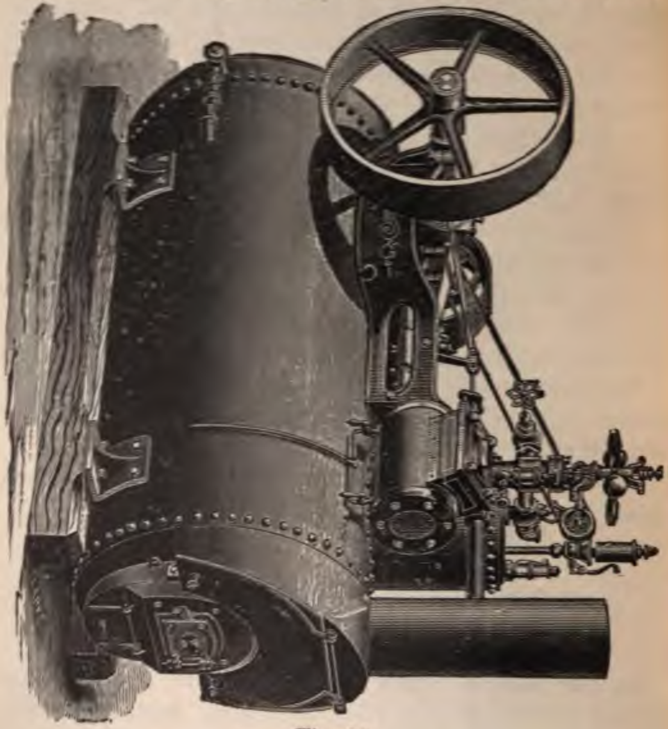


Fig. 35.

The Bookwalter Engine.

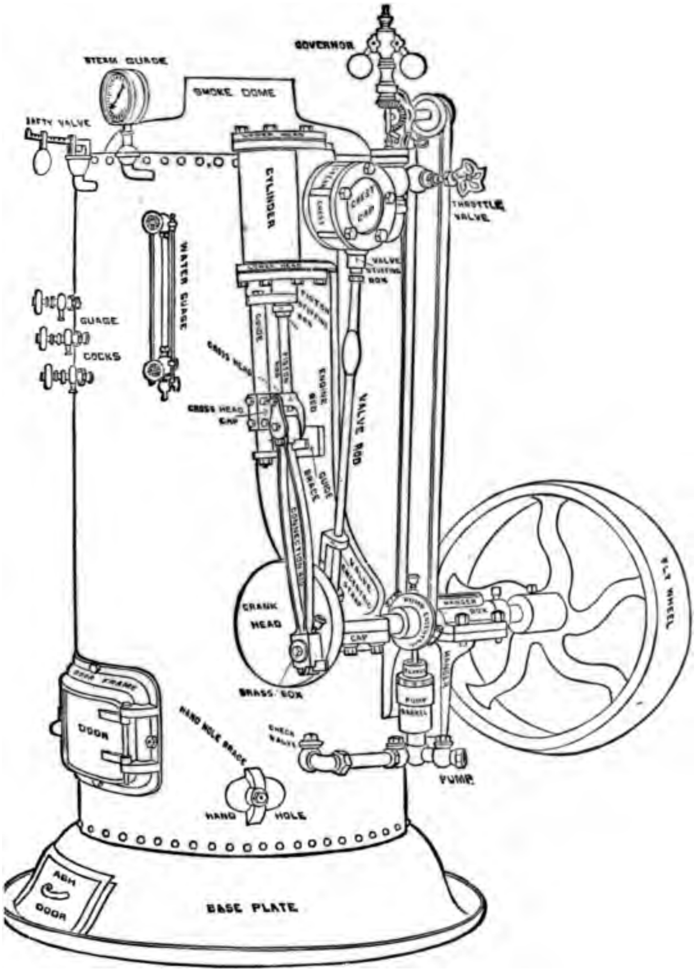


Fig. 34.

The Bookwalter Engine.

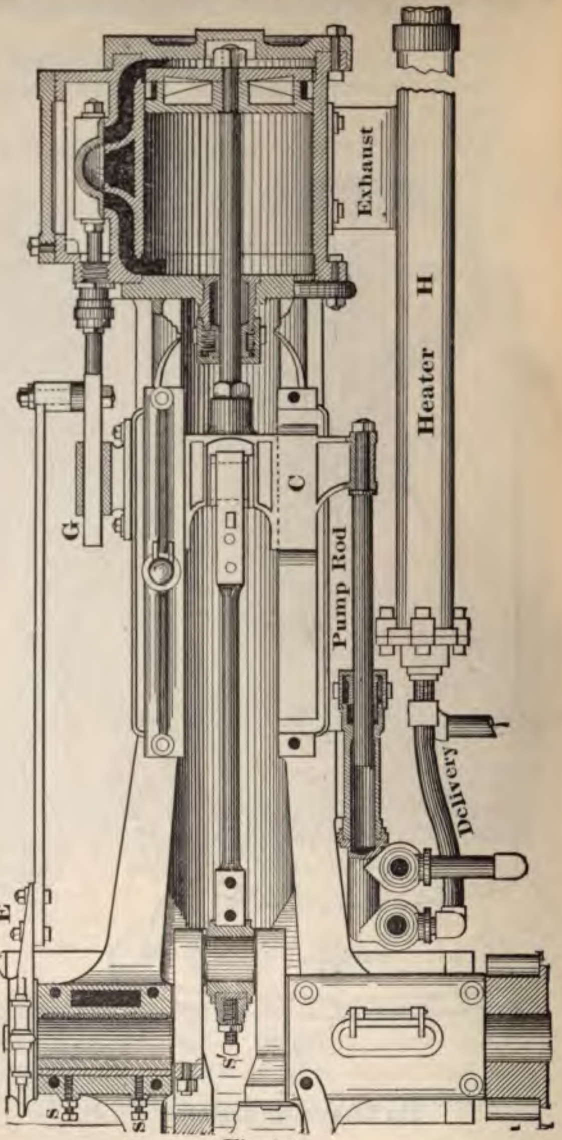


Fig. 36.

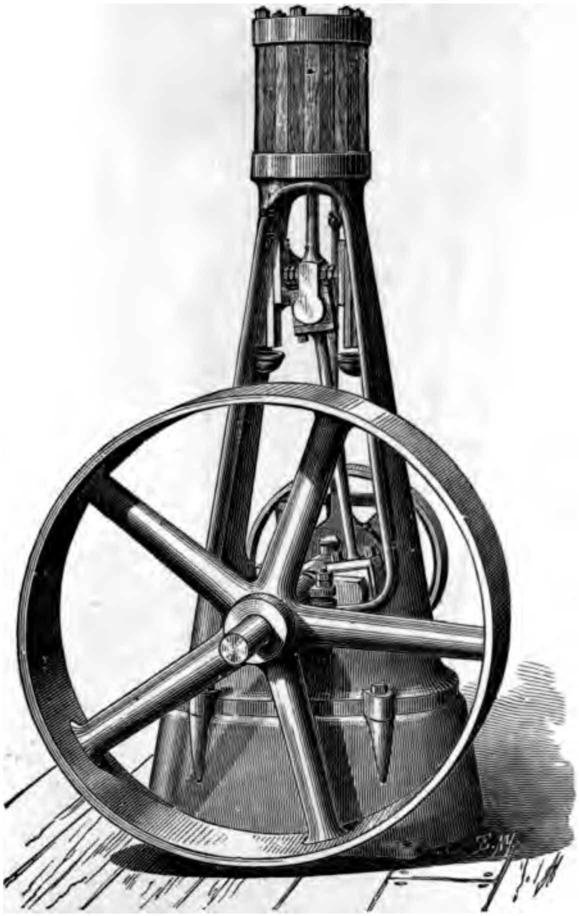


Fig. 37.

Vertical Engine with Common D or Plain Slide-Valve.

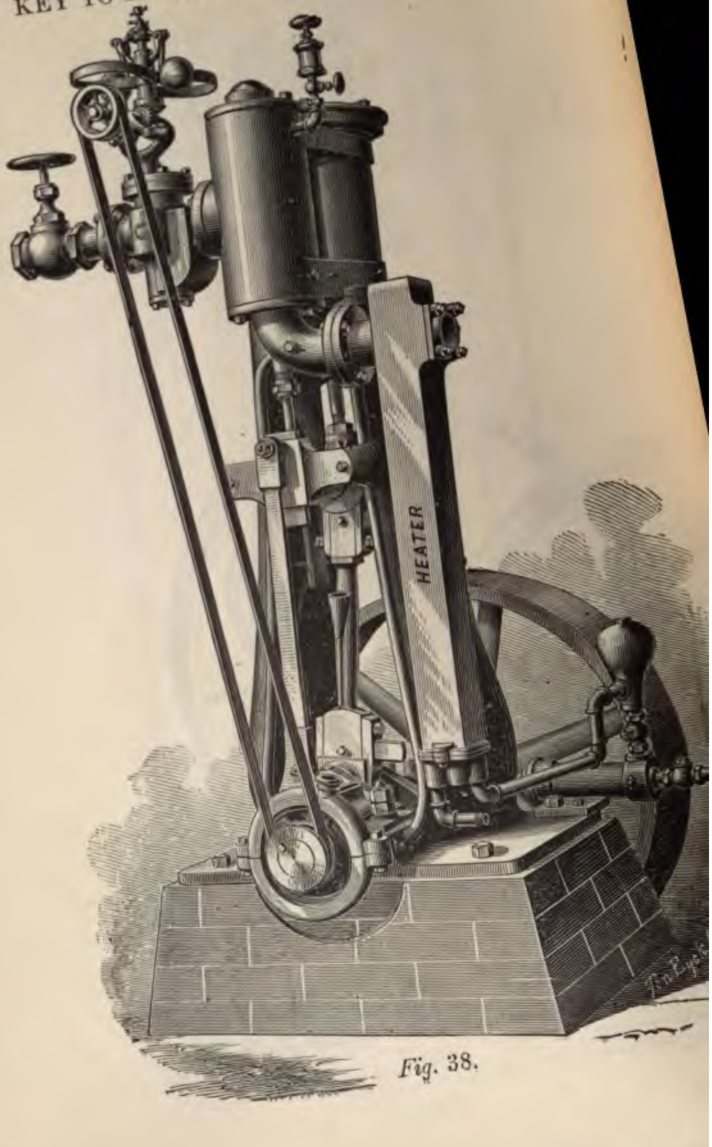


Fig. 38.

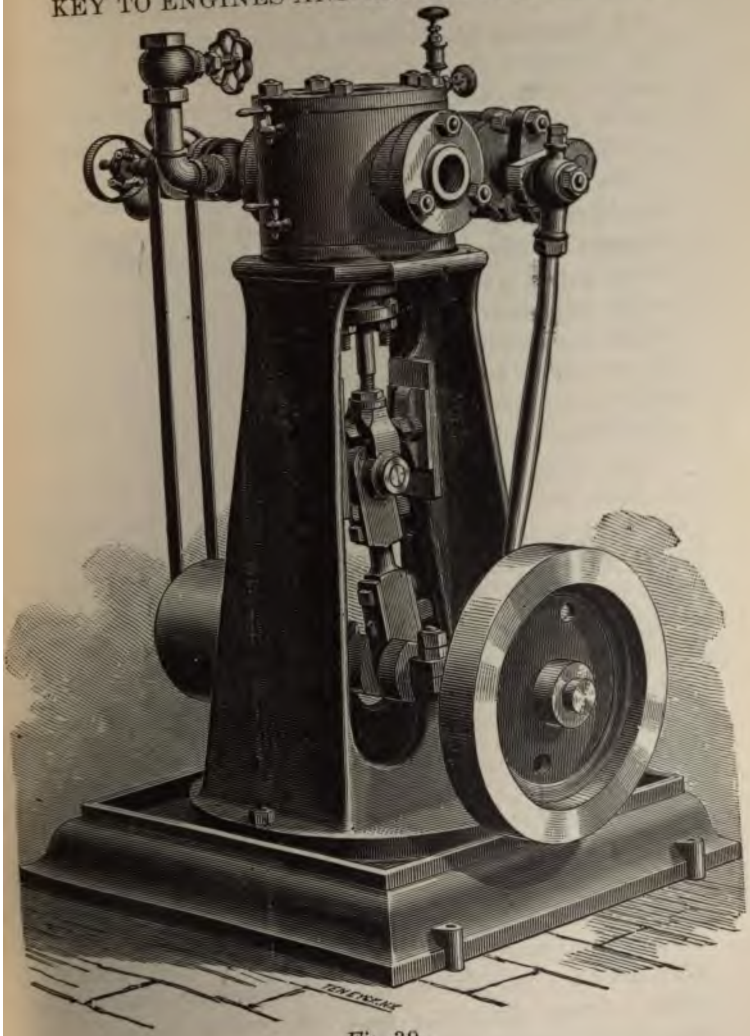


Fig. 39.

A Common Slide-Valve Vertical Engine is show [illegible] represents a common form of this cha [illegible] The guides for the cross-head are sometimes [illegible] and at others are bolted on so that they [illegible] resurfaced after they become worn.

[illegible] these guides are sometimes made flat, [illegible] flanges on each side, and at others concave, [illegible] cross-head sideways. If the center of the c [illegible] axis of the piston-rod, the cross-head [illegible] so as to keep the axis of its pin parallel to th [illegible] In order to take up the wear betwe [illegible] and the guides, the cross-head is provide [illegible] screws, whose nuts are seen on each sid [illegible]

[illegible] represent vertical engines, by the Morris [illegible] are center crank engines, but that [illegible] provided with a valve, whose spindle is [illegible] hence no guide is necessary for the [illegible] piston-valve is employed, the valve-rod [illegible] by a rectangular guide. The connecting rod straps are secured by a bolt, thus dispensing with the g[illegible] The exhaust steam passes direct into the top of the heater.

Hoisting Engines usually have vertical boilers and horizontal engines.

Fig. 40 shows Mundy's Engine for Pile driving and quarrying purposes, in which the engine having lifted the weight, the latter is lowered independent of the engine motion.

The engine drives the small pinion shown in fig. 41 and the large gear driven by the pinion has a cone (shown on the left side of the gear) fitting into a corresponding cone in the hoisting drum. By means of a rod passing through the shaft of the hoisting drum, the grip between the two cone may be regulated. When a load is to be hoisted the cone

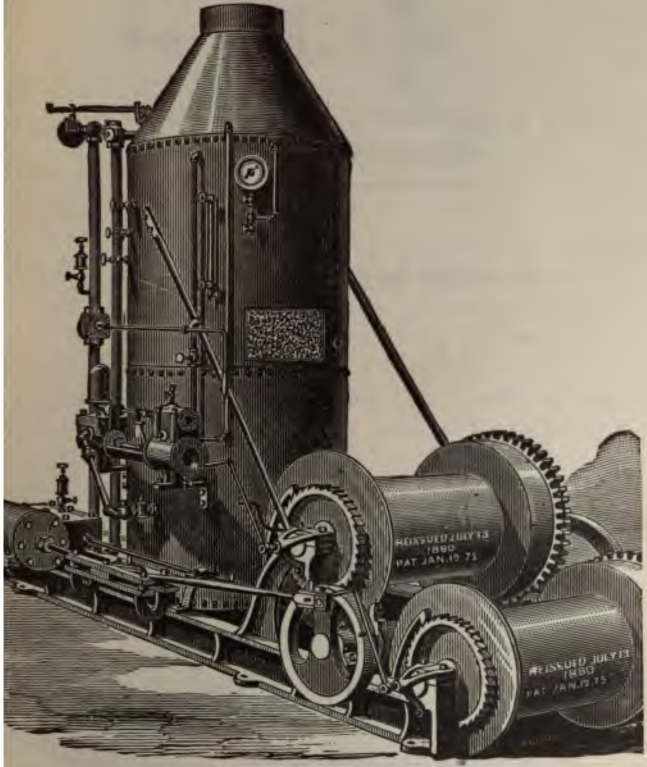


Fig. 40

Mundy's Hoisting Engine.

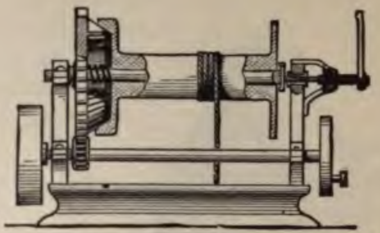


Fig. 41.

The Friction Gear of Mundy's Hoisting Engine.

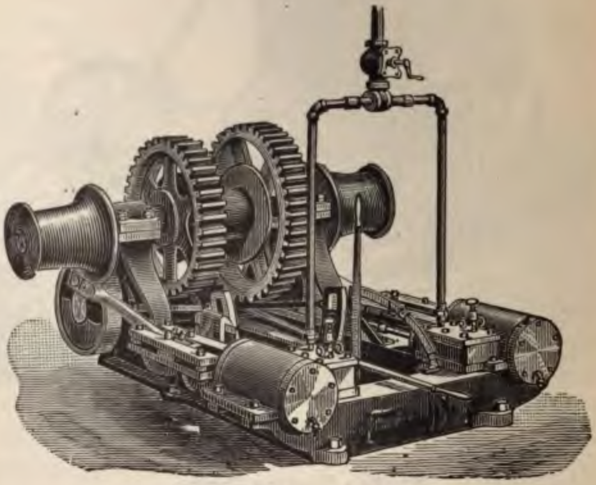


Fig. 42.

Mundy's Steam Disk Winch for Vessels.

are locked firmly together, but in lowering, the friction between them may be so regulated that the drum will slowly revolve unwinding the rope while the engine is at rest.

The driving pinion operates both drums, and as each drum has a friction device, the drums may be used separately, thus for quarrying purposes one drum may be for hoisting purposes, and the other for swinging or lowering the boom. The pawl and ratchet shown at the end of each drum, is for holding the weight with one drum, while the other is operating the boom.

It is obvious that the drum will only unwind when caused to do so by the weight, hence friction hoists are used when the duty consists of lifting only. For general purposes therefore, hoisting engines are provided with reversing gears, usually the link motion. Fig. 42 shows a deck winch engine for vessels. Two cylinders are here used, the cranks being at a right angle one to the other, and a link motion being used for reversing purposes.

Fig. 43 represents a horizontal center crank plain slide valve engine, by Smith, Meyers & Schnier. The eccentric is here placed inside the frame, the eccentric-rod having an offset to enable it to clear the frame. The steam-chest and valve are inclined, and the governor and steam pipe are on one side of the steam-chest.

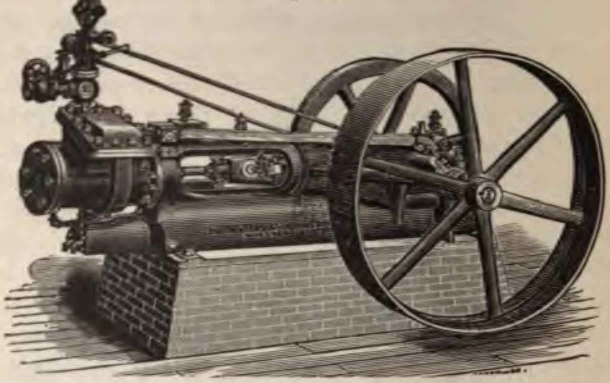
The cylinder overhangs the end of the frame, which extends over the top of the cross-head; access to which is obtained from openings on the side of the frame. This affords a rigid frame, which is not disturbed by the expansion and contraction of the cylinder.

PISTON VALVE ENGINES.

An Example in Engines with piston valves, is shown in Figs 44, 45 and 46. The valve consists of a hollow piston or sleeve, surrounded in the middle of its length by the live steam, the exhaust of the crank-end of the cylinder passing through the bore of the valve. The live steam enters at the top of the cylinder, and passes around a jacket to the valve below. The valve is driven from a rock-shaft worked from an ordinary eccentric.

The pump for feeding the boiler is driven from an eccentric, and is situated above the heater, as shown in Fig. 45, the water being pumped in at the end of the heater, which contains tubes into which the exhaust steam passes.

Fig. 43.



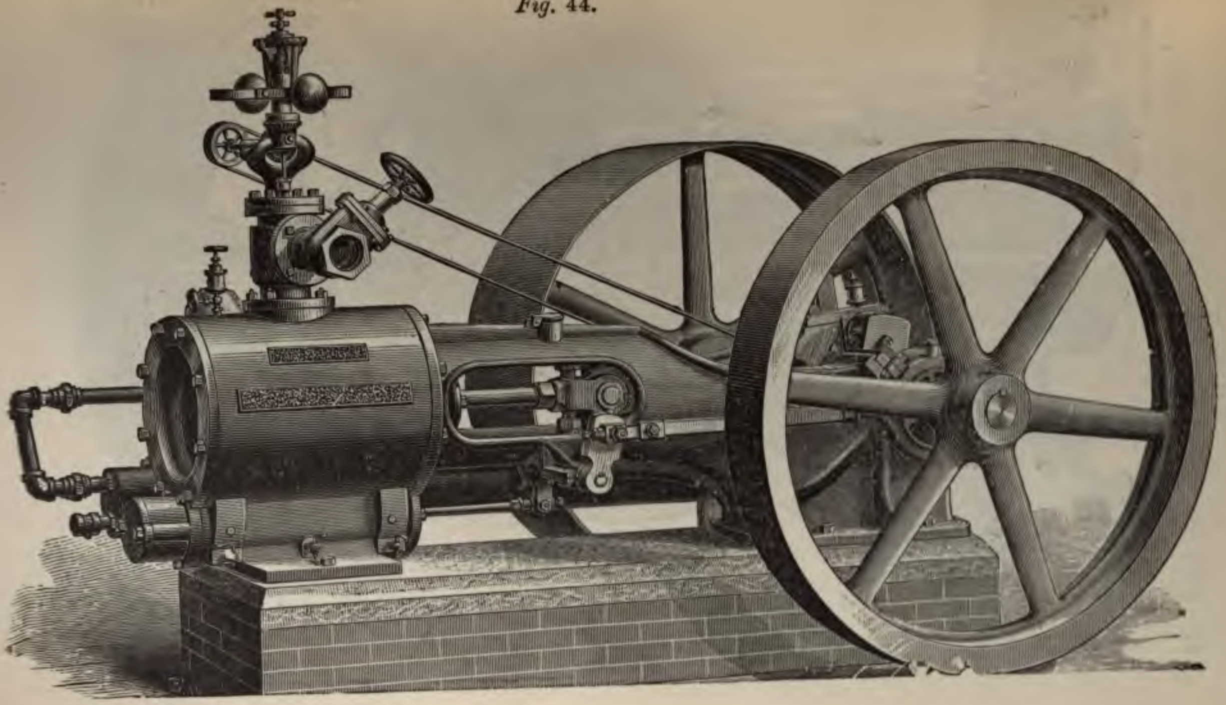
In Fig. 46 the piston is shown at the end of the stroke at the head-end of the cylinder, the course of the steam being denoted by the arrows.

Forward Running Engines are those in which the top of the fly-wheel runs towards the engine cylinder.

Backward Running Engines are those in which the top of the fly-wheel runs away from the cylinder.

A Right Hand engine is one in which the fly-wheel is on the right hand of the observer when he stands at the head-end of the cylinder. Left hand engines will have the fly-wheel or main driving pulley on the left.

Fig. 44.



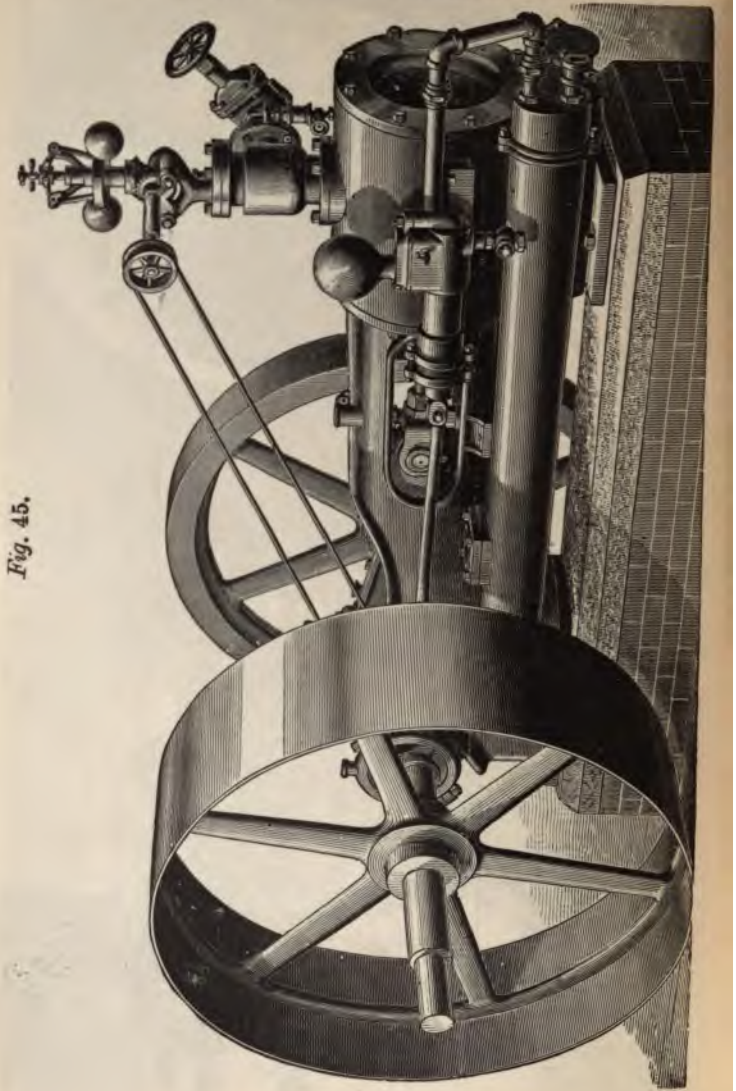


Fig. 45.

Sectional View of a Horizontal Engine Having a Piston-Valve.

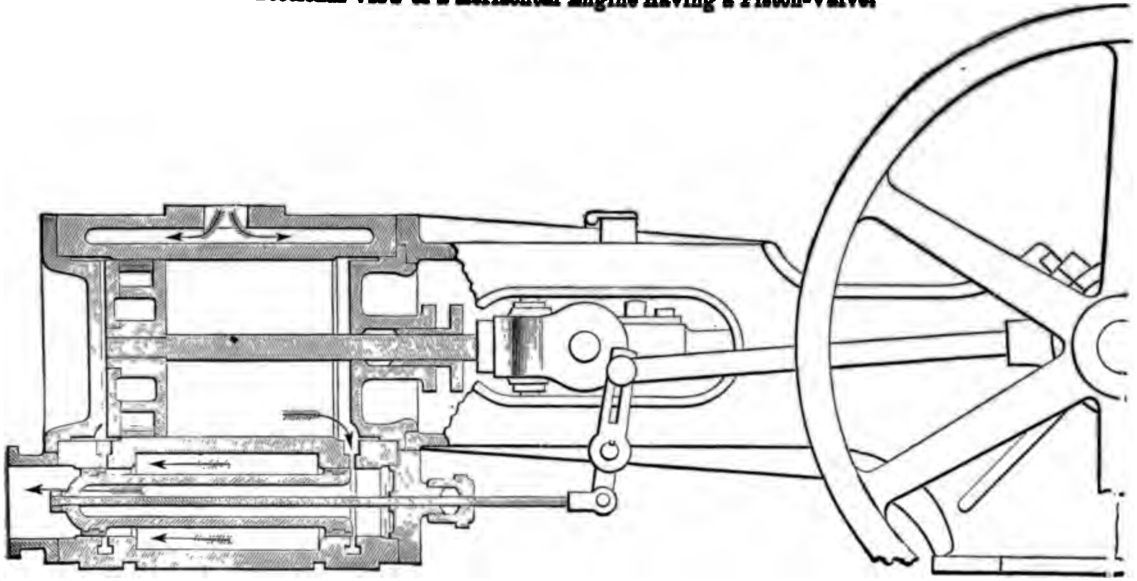


Fig. 46.

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART III.

What are the first things to do in starting a plain slide-valve engine?

What is the best position for the crank to be in for starting.

What would constitute a thorough examination of a plain slide-valve engine if the engineer did not know its condition?

What would be the examination an engineer should make of a plain slide-valve engine if called upon to start it as quickly as possible without knowing its condition?

In what order should a thorough examination be made of the engine?

What is a lead used for in adjusting the fit of a brass to its journal?

How would you take a lead?

When a lever is used between the two brasses what does the fit of the top brass depend upon?

In oiling the engine what precaution would you take to prevent the journals from heating?

How would you find out if the connecting-rod was of the right length to give an equal amount of clearance at each end of the cylinder?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART III.

CONTINUED.

How would you test whether the slide-valve was set properly?

Is the practice of "squaring" a common slide-valve correct?

What effect does the wear of the crank-shaft in its bearings and the wear of the valve motion have when the cylinder is above the crank?

What when the cylinder is below the crank?

What would you do if the crank-shaft bearings began to heat?

What part of the engine is the most likely to get hot from the friction of the fit?

What are the principal causes of hot crank-pins?

PART III.

STARTING A PLAIN SLIDE-VALVE ENGINE.

The Method to be Pursued before starting a plain slide-valve engine depends upon what the engineer knows about the condition of the engine.

If he knows the engine is in proper running order, all that is necessary is to first attend to the oil cups and start them feeding.

Then, if it is necessary, move the crank into the required position to start it easily; open the waste water cocks to relieve the cylinder of the water that will be condensed from the steam when it enters a cool cylinder, and turn on the steam; giving the throttle valve enough opening to start the engine slowly.

The Best Position for the crank-pin to be in to enable its starting easily, is midway between the horizontal and vertical position (or, in other words, at an angle of 45° to the line of centers) and inclining towards the cylinder, so that when the engine moves the piston will travel towards the crank-shaft.

There are Two Reasons why this is the best position for starting. The first applies to all engines because there is a greater piston area for the steam to act on when the piston is moving towards the crank, than there is when it is moving away from it. This occurs because the piston-rod excludes the steam from a part of the face of the piston. The second applies to all plain slide-valve engines whose slide-valves have equal laps and both steam-ports of equal widths, and is that the live steam follows further on the stroke when the piston is moving towards the crank than it does when it is moving away from it, and it follows that more piston power is developed, and the engine is less likely to stop when passing the dead center.

When First Taking Charge of an Engine it is proper, before starting it, to ascertain that it is in fair working order.

A Complete Examination of an Engine should include a test of the fit of the piston to the cylinder-bore; of the cross-head to the guide-bars; of the connecting-rod brasses to the crank-pin and cross-head journals; and of the crank-shaft to its bearings. It would also include a testing of the alignment of the crank-shaft and of the guide-bars, as well as the set of the valves and the adjustment of the governor.

The Least Examination Permissable with a Due Regard to Safety would be to move the engine throughout at least one full revolution by hand, and to see that the connecting-rod brasses and the main bearings do not fit too tight to their respective journals, and to then start the engine slowly by giving it only enough steam to move it, keeping the hand on the throttle valve so as to be able to shut off steam instantly should it become necessary.

A Thorough Examination should be made in the following order.

First slightly loosen the nuts on the crank-shaft bearings and also the connecting-rod keys.

Then move the fly-wheel around until the crank points straight to the cylinder, which will bring the piston up to the outer end of the cylinder-bore.

Take off the Cylinder-Cover and also the follower from the piston-head and see that the piston-rings are set out to fit the cylinder-bore but not to bind it tight. Then bolt the follower up firmly in place again.

Take off the Connecting-rod and move the piston until it touches the cylinder-cover at the other, or crank-end, of the cylinder, and then draw a line across the side face of the cross-head guide and of the guide itself.

Put on the cylinder-cover and push the piston back until it abuts against it, and then make another line on the cross-head guide and the guide-bar and these two lines will show the extreme positions to which the piston can be moved when the connecting-rod is disconnected.

Next put on the Connecting-rod, carefully adjust the keys or wedges so that the bores of the brasses fit easily to the crank-pin and cross-head pin, seeing that the oil holes are clear and that oil will feed properly to the journals.

In making this adjustment it is a good plan, if there is any end play of the brasses on the crank-pin, to set up the key or wedge until the rod can just be moved by hand on the pin, by first pulling the rod to one end of the pin and then pushing it to the other.

In putting on the rod it will be necessary to move the piston a trifle towards the crank.

In Making the Adjustment of the crank-pin fit to the rod brasses, it is a good plan to drive the key home until the brasses are known to bind the crank-pin, and then mark a line across the side face of the key and fair with the top face of the connecting-rod strap, to then slacken back the key enough to ease back the brasses to a proper fit, and then mark another line on the key.

The first line will form a guide as to how much to slacken back the brasses to adjust the fit, and the second one will form a guide as to how much the key is moved when making a second adjustment, if one should be found necessary after the engine has been running.

Similarly, in Adjusting the Main bearing boxes to the crank-shaft, either the nuts, or what are called leads, may be taken to adjust the fit. Leads are necessary when the joint faces of the brasses do not meet, but are left open so that the wear can be taken up while the engine is running.

It is better, however, to let the brasses abut together, so that it may be known that the fit is correct when the nut is screwed firmly home.

The Method of Taking a Lead is as follows: The top brass is loosened, and between the joint faces of the brasses or boxes on each side of the shaft, a piece of lead wire is inserted. For a shaft of say four inches in diameter, the lead wire shall be about $\frac{1}{16}$ inch in diameter, or for a 10 inch shaft the wire should be $\frac{1}{8}$ inch in diameter, and should be as long as the brass. The nuts are then screwed firmly home, and the wire will be squeezed between the brasses and thus flattened on two opposite sides, the thickness showing how far the joint faces of the brasses are apart when the bore grips the journal.

A Liner, Fit-Strip, Distance-Piece, or Shim (all these names meaning the same thing) is a strip of metal placed between the joint faces of the brasses to hold them the proper distance apart to make a working fit of the journal and brasses, when the latter are firmly bolted up.

The Fit of the Top Brass therefore depends upon the fit-strip being of the proper thickness from end to end.

Now the Lead Wire is the gauge for the thickness of the fit-strip, the latter being made a trifle thicker than the flattened sides of the lead.

If the Lead is Thicker one end than the other, or if one lead is thicker than the other, the fit-strips must be made so, and the leads must be marked so that it may be known which way they were placed between the brasses so that the proper fit-strip may be on the proper side of the brass, and the proper end towards the crank.

Another Method that is adopted in the case of large brasses, is to screw down the nuts until the brasses bind the journal, and then make a mark on the nut and on the bolt thread. The nut is then slackened back as much as the judgment dictates, and a note made of how much this is, the marks forming a guide.

As the wear takes place, and the nuts screw farther down, a new mark is made on the nut so that it may always be known how much to screw up or unscrew the nut, to make a light adjustment.

To Avoid Heating it is a good plan to press some tallow into the bottom or in one corner of the oil cup, and then pour in the oil used for ordinary lubrication. So long as the bearing remains cool the oil will feed and the tallow remain.

If the Bearing Heats, the tallow will melt, and having a heavier body will give a more suitable lubrication.

To find if the connecting-rod is of the right length to give, as it should do, an equal amount of clearance (or space between the piston and the cylinder-cover) at each end of the stroke, move the fly-wheel a trifle in either direction, and then move it back until the crank is on the dead center, and draw a line across the cross-head guide and guide-bar, and the distance between this line and that drawn when the connecting-rod was disconnected, shows the amount of clearance at that end of the cylinder. Then move the crank-pin over to its other dead center and mark a line across the cross-head guide and the guide-bar, and the distance between this line and that drawn before the connecting-rod was put on, will show the clearance at this end of the cylinder.

If the clearance is not equal for the two ends it should be made so, by putting liners behind the connecting-rod brasses so as to lengthen or shorten the connecting-rod (according as the case may require), and equalize the clearance, while at the same time bringing the connecting-rod keys up to their proper heights.

To Test the Set of the Valve the steam-chest cover must be taken off, the crank placed alternately on each dead center, and the lead measured for each port.

An unequal or an equal degree of valve lead may be given by suitably altering the length of the eccentric-rod, but when the lead is equal for the two ports, its amount must be regulated by moving the position of the eccentric upon the crank-shaft.

Squaring a Valve. A method not uncommonly pursued in setting a valve is to what is call *square it* before trying it.

This squaring process consists in so adjusting the length of the eccentric-rod that the valve travels an equal distance over or past the steam edge of each steam-port; but since the valve does not, when set to give equal lead, travel equally past each port, therefore the work done in squaring a valve is all thrown away, and may result in altering the eccentric-rod from its proper length to an improper one, necessitating that it be altered back again in order to set the lead right.

The Proper Method is to adjust both the length of the rod and the position of the eccentric, by testing the lead at once, lengthening the eccentric-rod to increase the lead at the crank-end, or vice versa.

Each Alteration of Eccentric Position may render necessary an alteration of rod length, or vice versa, each alteration of rod length may render it necessary to alter the eccentric position, hence the lead should be tried at both ends of the cylinder after each alteration of either rod length or eccentrc position.

In Vertical Engines the weight of the crank-shaft causes it to wear the bottom brass or part of the bearing box the most thus lowering its position, while the eccentric straps and pins wear most in the same direction, hence the wear increases the lead at the head-end of the cylinder when the latter is above the crank, and at the crank-end when the crank is above the cylinder.

When the Cylinder is Above the Crank the weight of the piston, cross-head and connecting-rod is counter-balanced at the end of the downward piston-stroke by giving the crank-end port more lead; but when the cylinder is below the crank it is the head-end port that must be given increased lead to prevent a pound or knock, or to allow for the wear downwards of the parts.

After an engine is started the pet-cocks should (if they are not automatic), be closed as soon as dry steam issues, and if this cannot be seen, it may be assumed to occur after the engine has made about 20 revolutions.

The parts that will then require particular attention, are the crank-pin, main bearings, cross-head guides and the pump, if there is one. The former must be kept properly lubricated, so that they may not get hot and the cylinder lubricator (which is usually placed on the steam-pipe), must be set to self feed properly.

If the Crank-Shaft Bearings should begin to heat, loosen the cap bolts and lubricate more freely, or if it is at hand some melted tallow may be applied with the oil as a heavier lubricant may stop the heating.

The crank-pin requires the most attention and is the most difficult to keep cool and to examine, because of its circular path rendering it difficult to feel it. This may be done however, in two ways, first by standing at the end of the engine bed and gradually extending the hand, until the end of the rod meets it as it passes, and second, by placing the hand on the connecting-rod as near to the end of the guide-bar as possible where its motion is diminished and moving the hand towards the crank-pin, by which means the end of the crank-pin may be approached gradually.

If the end of the rod is hot the engine speed should be reduced or the engine should be stopped so that the connecting-rod key or wedge may be eased back, and the oil feed made more copious. Then, after the engine has been stopped for the night, the brasses should be taken out, and any rough surface either on the brasses or on the pin smoothed down with a file.

Hot Crank-Pins may occur from several causes, but by far the most common ones are from improper oiling, or from the engine being out of line.

A heavier oil will often stop, or at least modify, the heating, but its cause should always be discovered and remedied.

* * *

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART IV.

What is an automatic cut-off engine?

What are the principal forms of automatic cut-off engines?

What kinds of governors do engines with releasing valves have?

What class of engine is the best representative of engines having a releasing gear?

How many valves does a Corliss engine have?

Explain the action of a Corliss valve-gear

What duty does the latch-link or crab-claw of a Corliss valve gear perform?

What means are employed to trip the admission valve?

What determines the point of cut-off and how does it do so?

What closes the valve?

What is a dash-pot?

What enables the dash-pot to work noiselessly?

How is the amount of air cushion in the dash-pot regulated?

What shape is a Corliss valve and how far would its lap, as ordinarily constructed, carry the live steam period, leaving the cut-off mechanism out of the question?

In stopping a Corliss engine what position would it be best for the crank to stop in?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART IV.

CONTINUED.

What would you do if you found the engine was about to stop on the dead center.

What is a starting bar and what is it used for?

How would you start a Corliss engine?

How should the fit of a Corliss valve be adjusted?

To what distance should the dash-pot piston fall?

How can a Corliss valve be constructed to enable it to follow up the wear?

Does increasing the speed of an engine cause it to require more skill to run it?

What governs the position the latch-link must be in after the cut-off has occured, in order to keep the lead eqaal?

What adjustments of a Corliss valve-gear will vary the valve lead?

What effect upon the lead does altering the length of the dash-pot rod have?

What effect upon the lead does lengthening the rod from the wrist-plate have on the valve at the head-end of the cylinder?

What adjustments would you make if the engine had been running a very light load, and required to be adjusted for a heavy load?

PART IV.

CORLISS ENGINES.

An Automatic Cut-Off Engine is one in which the governor operates mechanism which varies the point of cut-off, and thus proportions the power of the engine to the resistance of its load and causes it to run at an uniform speed of revolution.

There are two Principal Forms of automatic cut-off engines, first, those in which the steam-valve spindle or rod, is released from the parts that move it to open for admission, while dash-pots, weights or springs close the valve to effect the cut-off; and second, those in which the travel of the valve is varied so as to alter the point of cut-off.

The first usually employ fly-ball governors, which actuate cams or stops to trip the valve. The second usually employ wheel governors or speed regulators as they are sometimes termed.

The Corliss Engine is the best representation of engines having a releasing gear, a general view of a Corliss engine being shown in Fig. 47, and a side view of the mechanism for one valve being shown in Fig. 48.

THE PRINCIPLES OF A CORLISS VALVE GEAR.

The Admission Valve. The stem of the admission valve is shown at *s*, fast on this stem is a bell crank *r r* worked by a rod C from the wrist-plate, which is reciprocated on its center by the rod M, that is worked from an eccentric which is fast upon the crank-shaft.

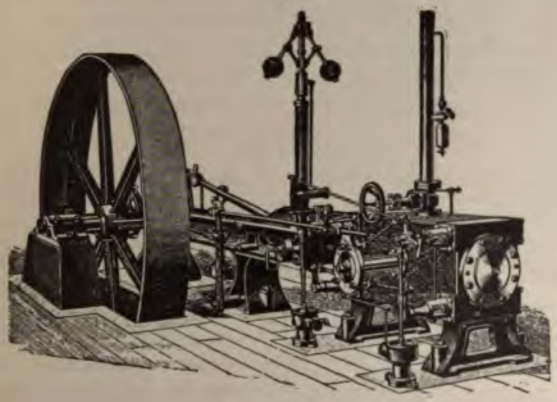


Fig. 47.

The Latch-link *a* is pivoted on the end of *r r*, and is more clearly seen at *u′* in Fig. 49. It has two legs, in one of which is a notch or recess which engages and disengages a latch-block that is pivoted on the end of an arm which is fast on the valve spindle.

With the parts in the positions they occupy in the figure the latch-block cannot be seen. It is, however, seated in a recess in the latch-link *a*, so that supposing the rod M to move to the right, *a* will be raised, and will, through the medium of the latch-block, revolve the valve stem *s* and cause

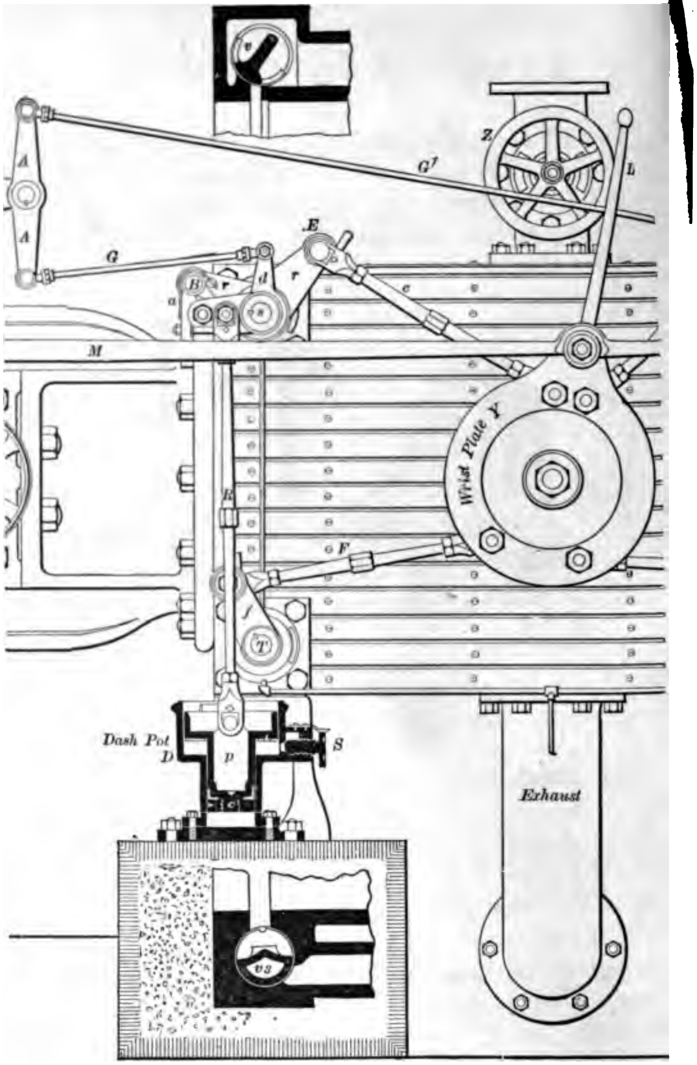

v
A
A
G'
Z
L
E
G
B
r
d
r
a
s
c
M
Wrist Plate Y
E
F
f
T
Dash Pot
D
p
S
Exhaust
v2

Fig 48

the valve to open the port at that end for the admission, which will continue until the latch-block is tripped out of the recess in a.

Latch-links are Sometimes Termed Crab-claws which arose from their shape resembling the claw of a crab; the term "latch-link," however, is more correct, because it is a link that latches and unlatches from the latch-block.

The Means Employed to Trip or Release the Valve is shown in Fig. 49 which shows the parts in position at the point at which the latch-block e (whose operating arm is removed from the valve spindle s' so as to expose e to view), is tripped from the recess shown in u' at w, hence valve stem s' is freed from connection with the latch-link and therefore free to move the valve and close the port for the cut-off.

The Point of Cut-off is determined by the governor, from the following construction: The latch-link u' has, it is seen in Fig. 49, two legs, in one of which is the recess w, while the end of its other leg (g) bears against the hub of the crank arm d' upon which is a cam piece or projection n'.

The arm d' is connected to the governor by a rod G', hence as the governor balls rise and fall they move the position of the cam n'. The latch-block e remains seated in the recess w (whose end y lifts e) until the end of the arm g meets the end of the cam n' and mounts upon it, which causes the latch-link to move upon its pivot in n', and its recess to move away from the latch-block and leave the valve free to close.

The Moment the Latch-block is Free from the latch-link the valve is closed by the action of the dash-pot or vacuum-pot as it is sometimes termed, the construction being as follows:

In Fig. 48 the parts are shown in the position they occupy when the piston is at the crank-end of the cylinder, and it is seen that the dash-pot piston is raised creating a partial vacuum beneath its lower end; as soon therefore as the latch-block

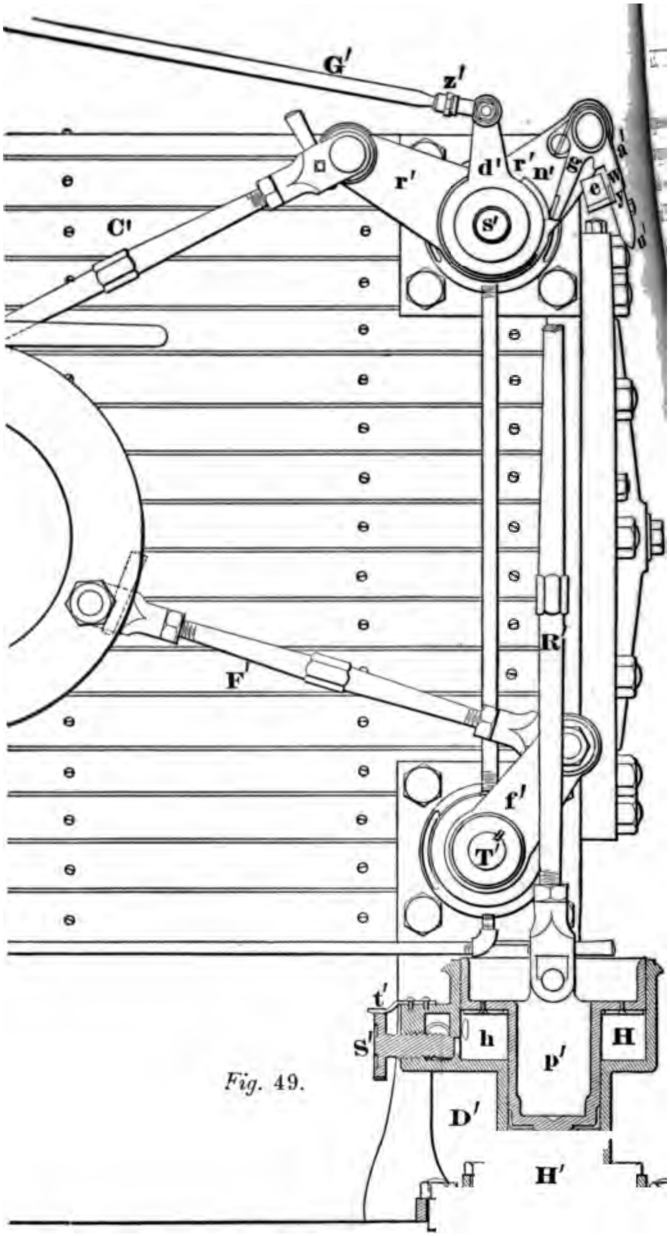


Fig. 49.

tripped the piston p falls, carrying with it the rod R which its upper end is pivoted to an arm that is fast on the valve [illegible]ndle or stem s, hence the valve is closed by the falling of [illegible] and R.

An Air Cushion is provided to enable the dash-pot to [illegible]at itself quietly, by means that are seen in Fig. 49.

In the enlarged bore H of the dash-pot is a hole h through which air can pass.

As the dash-pot falls, the air passes out through this hole until the dash-pot piston passes over it and closes it, after which the remaining air is compressed and acts as cushion.

To regulate the amount of air compression or cushion, a valve s' is provided, its stem being threaded so that its end may more or less close the bore of its seat, which passes into H. At t is a spring, which holds the head of valve s' in its adjusted position.

The Construction of the valves is shown in Fig. 48, which is a side elevation of one half of the cylinder, and shows the governor in connection with the valve gear at the crank-end. The valve gear is shown in the position it would occupy when the piston was at the crank-end of the cylinder with the crank on the dead center.

The admission valve v is shown in end section and removed from the cylinder.

The exhaust valve is also shown in end section removed from the cylinder. Both valves are shown in position corresponding to the positions occupied by the valve gear.

The valve faces are arcs of circles (of which the axis of the valve stems s are obviously the centers), and the steam or admission valve v is given steam lap sufficient, that if allowed to act independently or uninfluenced by the cam motion, trip motion, or releasing mechanism, live steam would follow the piston throughout about $\frac{7}{8}$ of the stroke. The latest point of cut-off permitted by the cam motion, however, is usually at about $\frac{5}{8}$ stroke. The admission valve *v* is shown open to the amount of the lead, and the dash-pot piston P raised from its lowest position to an amount corresponding to the lap and the lead of the admission valve.

Steam from the boiler enters at the top of the cylinder, the hand wheel for the throttle valve being shown at Z.

The exhaust passes out at the bottom of the cylinder.

At L is a lever or starting bar that is employed to start the engine, which is done as follows:

STARTING A CORLISS ENGINE.

In Shutting Off the Steam to Stop the Engine the engineer endeavors to regulate it, that the crank will stop at about $\frac{1}{3}$ of the way between a dead center and the vertical position.

It is best to let the crank stop in such a position that the piston is nearest to the head-end of the cylinder, the reasons for this having been explained with reference to starting plain slide-valve engines.

If he finds that the crank is about to stop upon the dead center, he operates the throttle wheel Z to let a little steam on, and taking hold of the right hand end of the rod M, he raises it so as to disconnect it from the wrist-plate. He then operates the starting bar L Fig. 48, to admit a little steam, and moves the crank very slowly to about midway between the horizontal and vertical position, so that it may be in the best position to start again. Or he may operate the starting bar to let the steam in on the other side of the piston, and stop the engine before it has travelled too far. Which of these courses he will pursue, depends upon the speed the engine is going at, but it will readily be seen that the use of the starting bar enables him to let in the steam on either side of the ton, or to shut it off, so as to stop the crank at the requir- point.

To Start the Engine again the engineer (after opening the cylinder drain-cocks or pet-cocks, if they do not work automatically) may, and usually does in the case of large engines, use the starting bar to let in a little steam alternately on each side of the piston so as to warm the cylinder before starting the engine. He then turns on the steam quickly, and with his right hand lifts the rod M up so as to disconnect it from the wrist-plate.

This Enables him to use the starting bar to hold the valve open and prevent the cut-off from occurring, by reason of the latch-link meeting the cam when the piston has made $\frac{5}{8}$ stroke as it would do if rod M was not connected.

If the crank should travel far enough to cause the valve to have been tripped and closed, the starting bar L can be used to open it again, and give a second admission, it being borne in mind that in starting it is best to let live steam follow nearly full stroke so as to heat the cylinder as quickly as possible, and prevent the pressure in the cylinder from rapidly reducing by reason of its condensation.

If, in attempting to start the engine, it should stop just before reaching the dead center, the starting bar is employed to cause steam to be admitted to the other end of the cylinder, causing the engine to move backwards until the crank-pin has reached a position favorable to start from in the proper direction, the starting bar may then be employed to open the valve and start the engine in the proper direction.

All that is Necessary to a proper use of the starting bar is for the engineer to familiarize himself with the direction in which it must be moved in order to open the port at the required end of the cylinder (which will enable him to use it without looking at the valve gear), and while watching the crank motion closely, operate the starting bar quickly, As soon as the crank (while running in the required dire tion), has fairly passed the dead center, the rod M should b hooked upon the wrist-plate and the starting-bar removed.

If the engine has a light load it will start the more easily and it may not be necessary to use the starting-bar to prolong the point of cut-off; but under a heavy load with the cam motion designed, as is usually the case, so as to give the latest point of cut-off at $\frac{5}{8}$ piston-stroke, the engineer will know that shortly after the crank has passed the vertical position the starting-bar must be used to keep the port open or reopen it, if the valve has been allowed to trip.

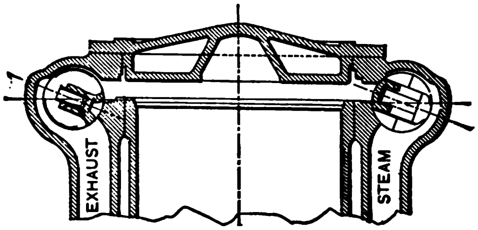


Fig. 50.

In Adjusting the fit of the valve it should not bed to its seat with any more force than just enough to keep it steam-tight, and it is best to adjust it while the cylinder is warm.

The Dash-Pot of a Corliss engine requires to be cleaned occasionally, and properly lubricated.

The amount of cushioning must be so regulated, that the dash-pot piston will fall to the bottom of the dash-pot without a pause, and without striking a blow when it seats itself.

In Some Corliss Engines the valve stems are fitted into recesses in the back of the valve, as shown in Fig. 50, which represents the upper end of the cylinder of a vertical engine. This construction permits the valve to move up to its seat and follow up the wear. On the other hand, however, reases the friction of the valve, and renders its lubrica-more important.

he adjustment and lubrication of the valve is a very im-tant point in running a Corliss, (or indeed any other gine), because if the valve sticks, or has excessive friction, e dash-pot cannot act properly.

A Modification of the Corliss valve as employed in the wiss engine, is shown in Fig. 51.

On the back of the main valve, is a separate cut-off valve whose stem passes through the stem of the main valve.

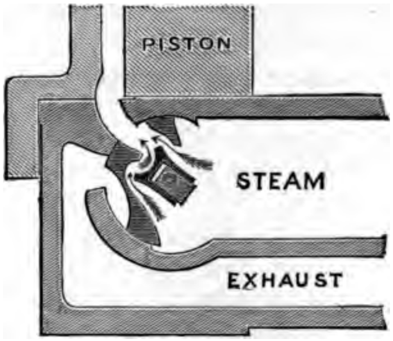


Fig. 51.

The main valve is a positive fit to its seat, while the cut-off valve is capable of sliding upon its stem to follow up the wear.

ADJUSTING CORLISS VALVE-GEARS.

In proportion as the speed of an engine is greater, more watchfullness is required in running it, because the greater the difficulty of preventing the parts from heating or pounding.

All the Directions Given with reference to the examination of a plain slide-valve engine apply to a Corliss engine (or to any other steam engine for that matter), while they are the additional points that the valve mechanism requires careful attention as follows:

The Latch-Block will be in its proper position to be caught by the latch-link at the required point in the piston stroke and thus keep the valve lead equal, so long as the dash-pot piston always falls to the same point in the dash-pot.

The Amount of the valve lead will be varied by altering the length of the dash-pot rod R (Fig. 48), or by altering the length of the rod C (Fig. 48), from the wrist-plate.

The First of these Adjustments alters the position of the latch-block, while the second alters that of the latch-link.

But altering the length of C′ Fig. 49, also alters the point of cut-off, because it alters the position of the latch-link with relation to the cam *n′*.

Now the Admission Valve having nothing to do with the exhaust, all it is required to do after the cut-off has occurred, is to remain steam-tight.

The Proper Adjustment is, therefore, to so regulate the length of rod R, that when the dash-pot piston is at its lowest position in the dash-pot, the steam valve will be in mid-position and will cover the steam-port equally on each side.

The Length of the rod C Fig. 48 should then be so adjusted, as to move the latch-link into position to lift the latch-block and give the required amount of lead when the crank is on the dead center.

A Line is Usually marked on the circumference of the hub of the bell-crank, to show the position to hinge the bell-crank to, when the crank is on the dead center, in order to give a certain amount of lead.

The Proper Adjustment of the rod G (that operates the cam arm *d*,) depends upon the speed the engine is to run at under a given amount of load, and must be made with reference to the amount of rise and fall of the governor balls, which will, whatever the amount of the engine load may be, stand at a given height for a given engine speed.

Suppose the governor balls to stand in the mid-position of their rise and fall, and lengthening G would cause the cut-off to occur later, and increase the speed of the engine, while shortening G would hasten the cut-off and reduce the speed.

If the Engine has a varying amount of load, the length of this rod should be such as to cause the governor balls to seat to mid-position under the average load, thus allowing an equal amount of margin for variation in either direction.

After the Engine is Started the first thing to do, is to see that the lubrication of all the parts is proceeding properly, especially that of the crank-pin, the main bearings, the cylinder oil feeder and the guide-bar oil cups.

It is a Good plan, when the engine has been running a little while, to take some of the oil that has been worked through the crank-pin, and smear it on a piece of white paper, and if the brasses are cutting, fine particles of metal will disclose the fact.

Both Heating and Pounding may occur from the engine being out of line or heating only may occur from this cause.

There is no remedy but to align the engine. If the main bearings are adjustable sideways, the engineer may try a slight adjustment of the boxes while the engine is running, but this is merely guess work.

Pounding may occur however, from insufficient cushioning for the speed the engine is running at, it being obvious, that the amount of cushioning required, increases with the speed of the engine.

The adjustment of the amount of compression for cushioning, is made by means of the rod F Fig. 48, it being obvious, that lengthening this rod increases the amount of compression because it causes the exhaust valve V³ to close the exhaust earlier.

The Point of Release however, is delayed by lengthening rod F, because by so doing the valve is revolved, so that its right hand edge (which effects the compression and release) covers the port more.

THE BROWN AUTOMATIC CUT-OFF ENGINE.

In this engine there are two separate induction or admission valves operating vertically, and two separate exhaust valves operating horizontally; both sets of valves are operated from the shaft A, which is driven by gearing from the crank-shaft, and drives a shaft B upon which are the eccentrics D operating levers E which are pivoted at their outer ends, and at their inner ends pass within a slot provided in the guides F of the induction valve spindle.

In connection with tongues or tripping pieces, the levers E lift the valves for the admission period, the point of cut-off being controlled by the governor as follows: The valve stem I is attached to a guide F, and in a slot in this guide is a tongue G. This tongue is pivoted in the guide, and has, at its upper end and within the slot of the guide, a catch or trip piece, beneath which stands the end of an arm E.

Now the Induction Valve is closed when at the bottom of its travel, and the weight of the valve and stem and the pressure of the steam (acting on an area equal to the area of the valve stem) are, combined, always acting to keep the valve at the bottom of its travel, that is, in its normal position, and there it remains until lifted for the admission of steam.

The Manner of Effecting this admission is as follows:

The Brown Automatic Cut-Off Engine.

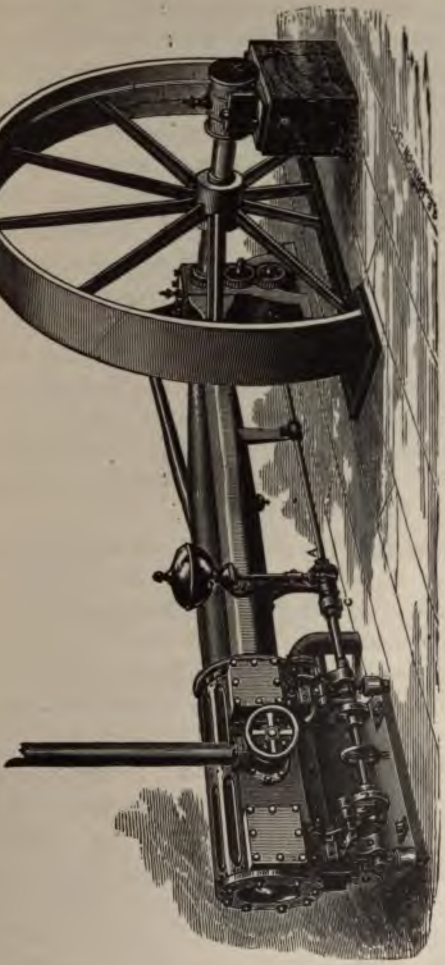


Fig. 52.

The end of the arm G acting against the catch on the upper end of the tongue, lifts the valve and holds it open so long as the tongue is not tripped. The instant, however, the latter action takes place, the valve, from its weight and the action of the steam upon the area above mentioned, closes, the movement being cushioned after the valve is completely closed, by means of the small dash-pot shown beneath.

It is Evident then that, by regulating the eccentrics, the valve may be given any desired amount of lead, and that the duration of the period of admission may be varied by tripping the tongue before referred to; and this is accomplished by the engine governor in the following manner: The governor acts upon a rod N, the end of the governor spindle being attached to a crank arm attached to this rod. Upon this same rod, and immediately behind the induction valve spindle guide F is an arm, standing vertically, and carrying a pin H standing horizontally.

Now the Tongue which, at one end, acts as a catch to the eccentric arm, at the other end protrudes from the back of the slide spindle guide, and stands directly beneath the pin, obviously then, the lever continues to lift the valve for the induction until the tongue is tripped by the pin, whereupon the induction valve is released, and descends, thus effecing the cut-off.

The Governor, therefore, by controlling the position or height of the pin H, controls the period of admission.

To Enable the handling of the valve when starting the engine, a friction device C is employed, being so constructed as to permit the hand-wheel M to be used to operate the valves independently of the shaft from the governor.

The Exhaust Valves lie horizontally, and are operated as follows: Upon a shaft are discs I which are provided with cam grooves. The rocker-arm K carries a friction roller which give to the exhaust valves a positive motion both to open and close the valves, thus avoiding the employment of dash-pots or vacuum pots.

The motion is such that the exhaust valves open and close very quickly, and remain nearly stationary during the rest of the stroke, and it follows, that being independent of the steam valves the amount of compression may be regulated at will, while when once set it will remain the same no matter what the point of cut-off may be.

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART V.

What is meant by the term "High Speed" engines?

What class of governor is usually used upon high speed engines?

What is the usual method of varying the point of cut-off on high speed engines?

In what respect is the "Straight-Line" engine an exception to other single slide-valve engines?

How many valves has the Buckeye engine and how are they driven?

State, in a general way, what a wheel governor consists of?

How are the centrifugal and centripetal forces adjusted in a wheel governor?

What is the peculiarity of the Armington-Sims engine?

Describe, in a general way, the Porter-Allen valve gear?

What are the important adjustments in the Porter-Allen engine?

What peculiarity of crank position when setting the valve-lead is there in the Porter-Allen engine?

Describe, in a general way, the valve balancing mechanism of a Porter-Allen engine?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART V.

CON6INUED.

What is the effect of shifting the eccentric across the crank-shaft?

What is the object of employing a separate cut-off valve, or expansion valve.

What effect on the amount of valve lead does the employment of a single valve have when it is shifted across the shaft to vary the point of cut-off?

PART V.

HIGH SPEED AUTOMATIC CUT-OFF ENGINES.

What are termed High Speed Engines are those whose pistons run at a velocity of more than about 600 feet per minute, some making as high as 800 or 900 feet in regular work. High speed engines are usually provided with an automatic cut-off, and a majority of them vary the point of cut-off, by means of shifting the eccentric across the shaft, so as to reduce the eccentric-throw, and therefore the valve

Fig. 53.

The Buckeye High Speed Automatic Cut-Off Engine.

travel. This causes the valve to cut off the steam earlier.

The eccentric, instead of being fixed upon the crank-shaft, has an elongated bore, and is hung on an arm that is pivoted at its other end after the manner of a pendulum. This arm is called the eccentric-hanger.

A Wheel Governor is usually employed to shift the eccentric across the shaft. In some cases, however, two valves are employed, one effecting the admission, the release and the compression, and the other the cut-off.

When two valves are employed, the lead, the point of cut-off, the point of release, and the point of compressson may be maintained equal for all points of cut-off; whereas when a single valve is employed, the lead, the point of release and the compression will vary with the point of cut-off, or, in other words, will be different for every different point of cut-off.

The Straight-Line Engine is, however, an exception to this rule, inasmuch as while a single valve is used, the valve lead and the points of cut-off are practically equalized.

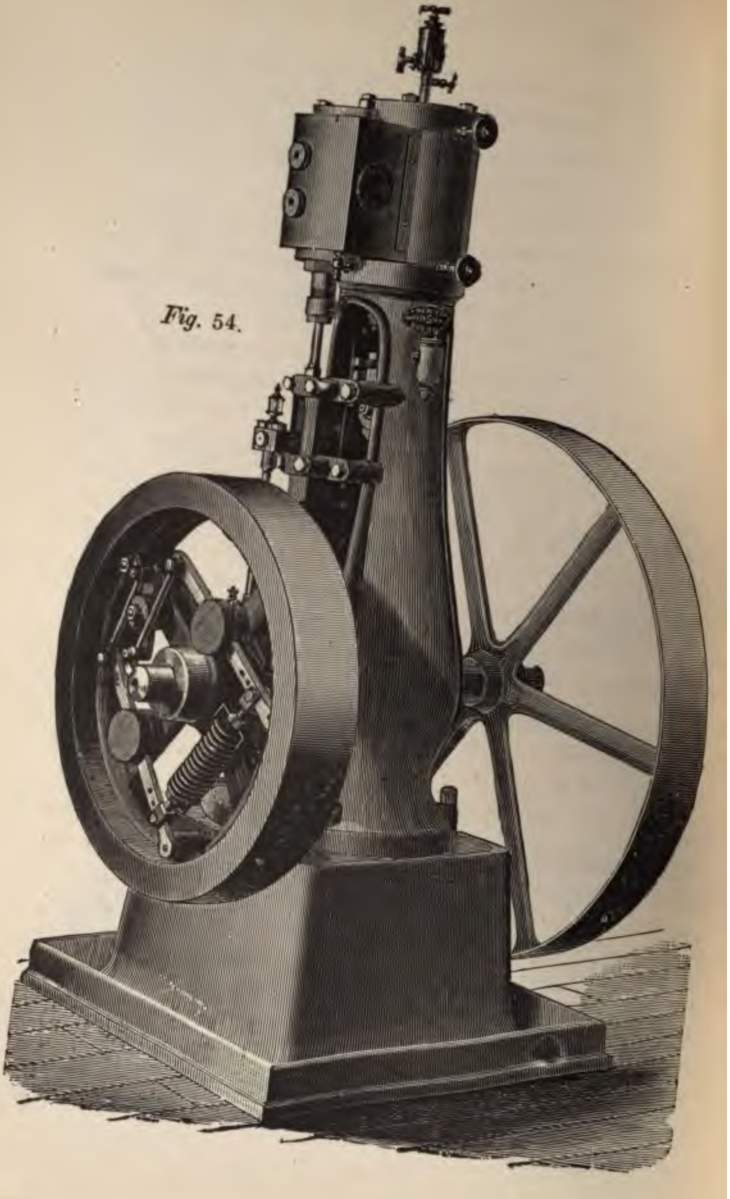
In the Buckeye Engine a main valve is used to govern the admission and exhaust, and a cut-off valve is used to vary the point of cut-off, and thus proportion the power of the engine to the amount of the load.

The Main Valve is driven by a fixed eccentric, hence the valve lead, the point of release, and the amount of compression is equal for all points of cut-off.

The Cut-off Valve is driven by an eccentric that is moved *around* the shaft (and not across it, as is commonly the case) by a wheel governor, hence the travel of both valves is equal for all points of cut-off, and the wear, both of the valves and their seats, is kept as equal as possible, which is an important element in keeping the valves steam-tight.

An Automatic cut-off engine, designed by the New York

Fig. 54.



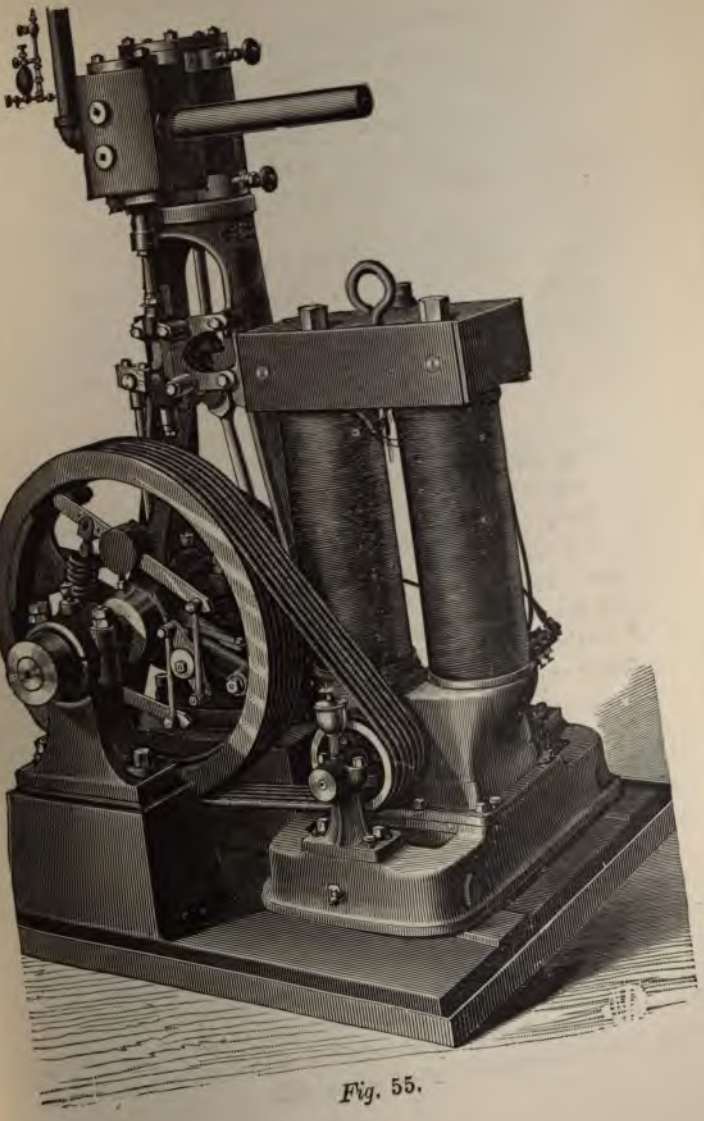


Fig. 55.

Safety Steam Power Company, is shown in Fig. 54. In this engine a wheel governor operates a piston-valve, taking steam at the ends and exhausting in the middle of its length, and the valve is balanced by giving to its two ends an equal area for the live steam to press against, and Fig. 55 represents the engine attached direct to a Dynamo for electric lighting purposes.

The valve spindle is provided with a guide, so that the side strain placed upon it by the eccentric-rod, may not cause undue wear upon the piston-valve, and it is necessary to keep these guides in proper line, and an accurate working-fit.

WHEEL GOVERNORS.

The General Principles upon which a wheel governor is constructed, may be understood from Figs. 56 and 57, the former showing the position of the parts when the eccentric is drawn in upon the crank-shaft to its position of greatest throw where it will be when the engine is at rest, and the latter showing the parts at their extreme outward positions, where they will be when the engine is running empty or without any load upon it.

S represents the shaft upon which is fast a wheel or disc A A, to which is pivoted the eccentric-hanger *c*, whose pivoting is shown at *d*. The eccentric C is fast upon *c* and connects by a pivot to the left hand weighted lever B, which is pivoted at *b* and connects by a link *e e*, to another weighted lever B, these two levers being diametrally opposite.

When the disc or wheel revolves, it carries all the parts with it, and the centrifugal force generated by the weighted levers B B, acts to pull the eccentric over and bring its circumference more nearly equal to the axis of the crank-shaft. This reduces the eccentric throw and therefore the valve travel, which hastens the point of cut-off.

The outward motion of the weighted levers is, however, resisted by the spiral springs D, which act to pull the eccentric inwards upon the shaft, and therefore to its position of greatest throw.

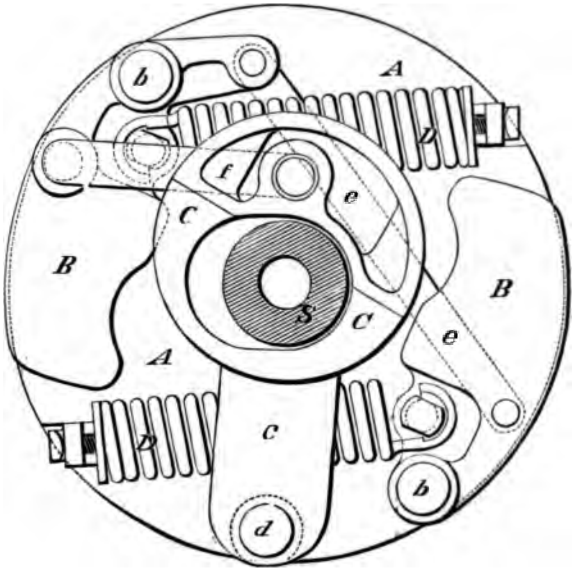


Fig. 56.

The diameter of the spring coils, and of the spring wires, so proportioned, that when the engine has, after starting, nearly attained its proper speed, the centrifugal force will overcome the spring tension and move the eccentric across the shaft.

As the springs are carried around by the disc, their tension becomes a centripetal force, acting in direct opposition to the centrifugal force of the weighted levers and the object is to so adjust the tension of the springs that it shall, as the weights swing outwards, increase in the same proportion as the centrifugal force increases, which latter increase occurs by rea of the weights swinging, as they move outwards, in a ci of larger diameter, and therefore moving at a greater vel ity.

The Spring tension may be varied to a certain extent by means of the screws shown at the outer ends of th springs.

If the Springs are used to Increase the spring tension the effect to prolong the point of cut-off at a given spe of engine and therefore to adjust the governor for a heavy engine load, whereas, if they are used to relax the spring tension and thereby diminish the centripetal force, the point of cut-off is earlier for a given engine speed, hence the adjustment is suitable for a light engine load.

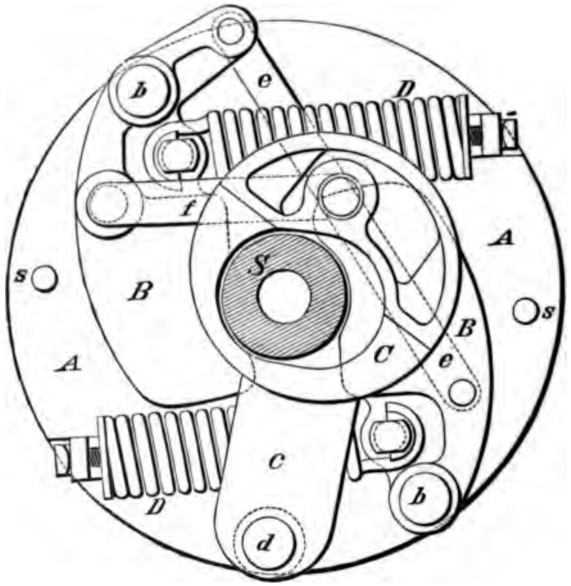


Fig. 57.

In the Governor of the Buckeye Engine [illegible] and [illegible] may be varied by increasing or diminishing the distance of the weights [illegible] which they swing.

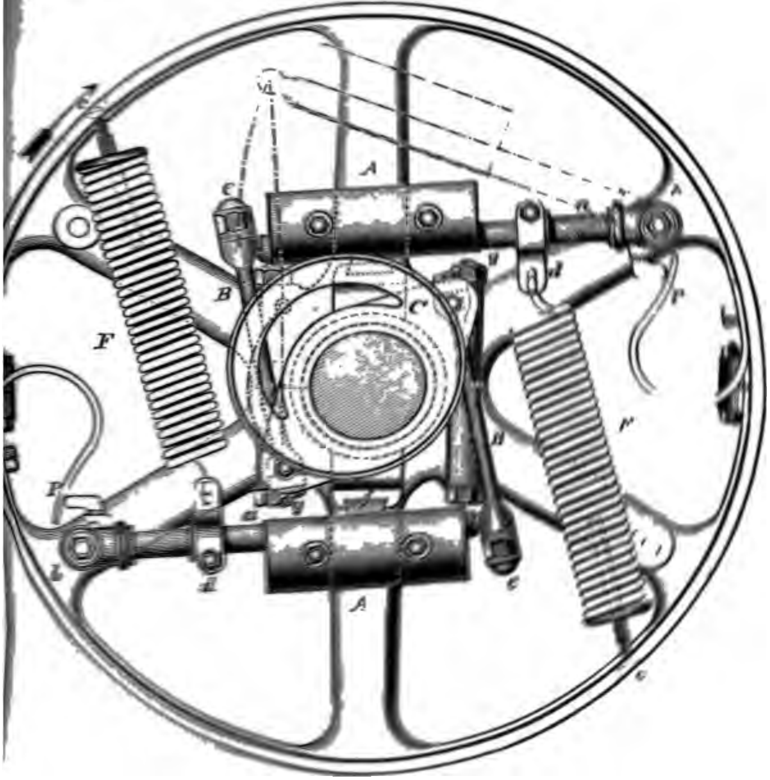


Fig. [illegible]

This is shown in Fig. [illegible] weights [illegible] are adjustable along [illegible] attachment [illegible] of the spring [illegible] adjustable.

This affords a wide range of adjustment of the centrifugal and centipetal forces.

The governor of the Armington-Sims engine is shown in Fig. 59. The eccentric is here made in two sections which are moved in opposite directions around the shaft.

These two eccentrics form virtually a single eccentric, whose throw-line (in whatever positions the two eccentrics may be placed) pass through the center of the outer eccentric or eccentric-ring.

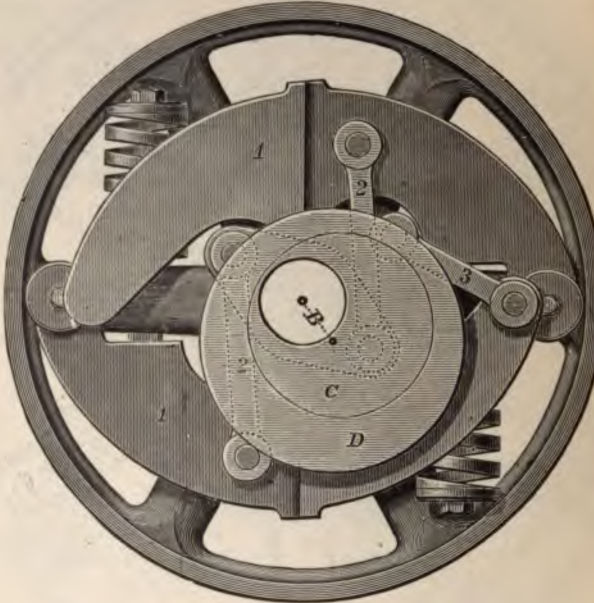


Fig. 59,

In the Ide governor, Fig. 60, the inner end of each spring is carried by a block capable of adjustment along a slideway. The tension increases in proportion as the block is moved outwards,

THE PORTER-ALLEN ENGINE.

In the Porter-Allen Engine a very accurate adjustment of the parts is necessary, partly on account of the high speed at which the engine runs, and partly on account of the refined construction of the valve-gear.

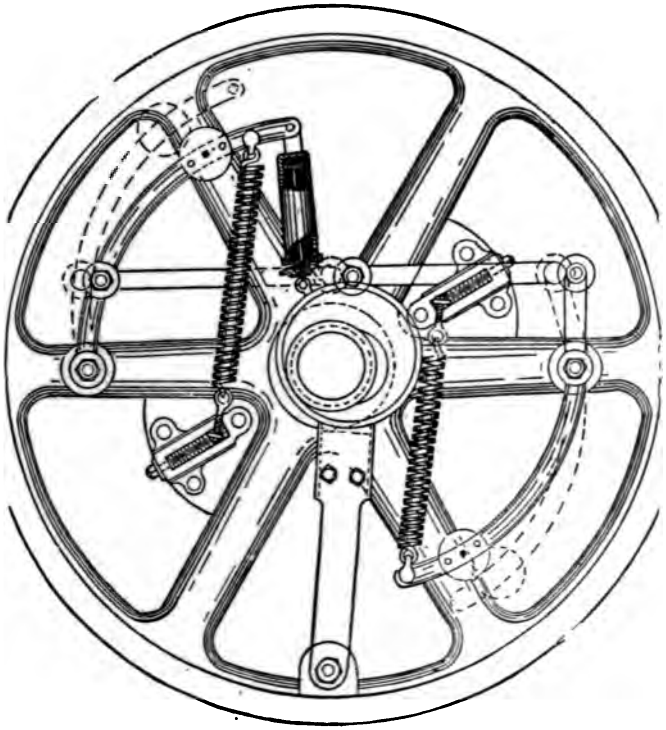


Fig. 60.

The Important Points to be observed in running this engine, are to maintain the link snpporting arm at the right height; to set the lead properly; to set up the valve balancing pressure-plate properly and to closely watch the lubrication of all the parts. This latter point, however, only has more importance than in other high speed engines, because the speed of revolution is greater than in other engines.

The Valve-gear consists of a link in one piece with one half of the eccentric-strap. The link-block is moved up and down the link-slot to vary the valve travel and therefore the point of cut-off, by a Porter governor. The link-block works a rod R operating a wrist-motion corresponding in its action to the wrist-plate of a Corliss engine.

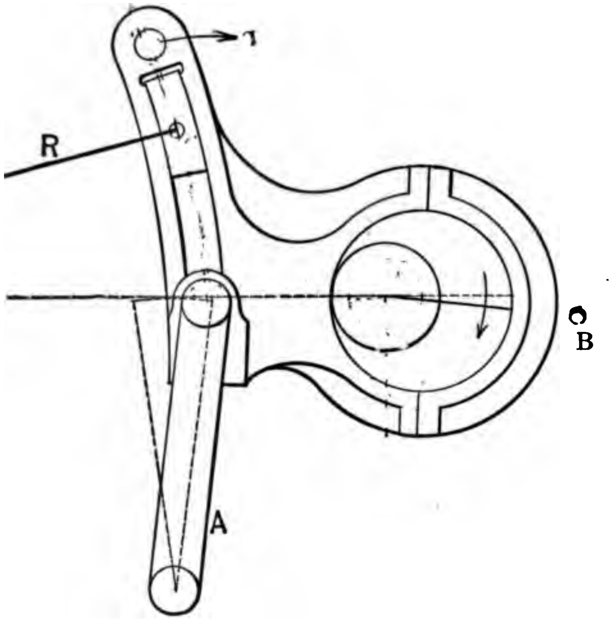


Fig. 61.

The valve is relieved of excessive pressure to its seat by means of a pressure-plate, between the face of which and the valve seat, the valve slides.

At the Top and Bottom of this pressure-plate are inclined planes, which fit against corresponding inclined planes provided on the valve seat, and beneath the steam-chest are set screws for adjusting the fit of the pressure-plate to the valve. The inclined planes cause the pressure-plate surface to keep parallel to the face of the valve.

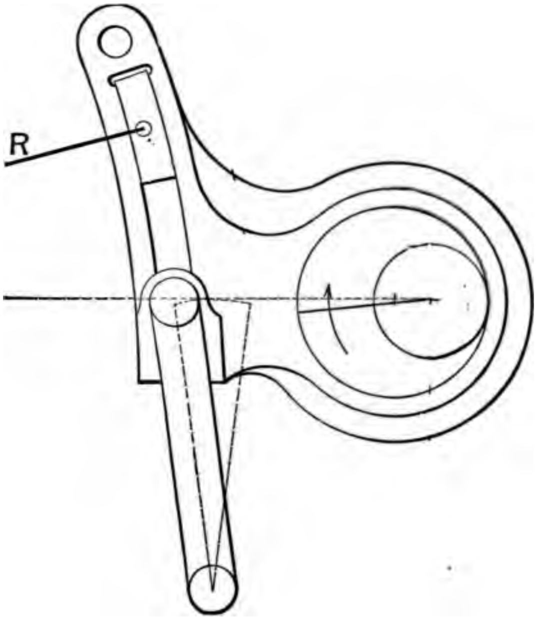


Fig. 62.

The exhaust valves are separate from the steam valves, and are on the other side of the cylinder.

The Adjustment Necessary to equalize the cut-off for all points is as follows: In Fig. 61 the link-motion is shown in the position it must occupy when the head is set for the crank-end port, the crank being at B; and in Fig. 62 it is shown in the corresponding position for the head-end port

In both cases the crank is below the line of engine center When in either of these positions the link-block can be move from end to end of the link-slot without moving the wrist-motion, and therefore without moving the valve.

The makers usually mark a line on the parts so that the crank may be set in this position, and this being done the height of the link supporting arm must be adjusted until the link-block can be moved from end to end of the link without moving the wrist-motion.

The top of the link supporting arm, A Fig. 61, must move in an arc that just meets the line of centers, as denoted by the dotted arc in the figure.

The Lead will, if made equal for each port when the parts are in these respective positions, be equal for each port for all points of cut-off, but not equal for the two ports.

The head-end port will have the most lead, and it is intended that it shall have. But whatever amount of lead each port is given it will remain the same, whatever the point of cut-off may be.

* * *

JESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VI.

ind of a reversing gear is in most common use?

the difference between a link-motion with open and one rossed rods?

es a link-motion affect the valve travel and what effect does ave on the admission?

fect on the valve lead does hooking up the link have?

t position is the link placed when the engine is to be l?

's the difference between Gooch's and Stephenson's link ı?

the difference in the action of these two link motions?

the objection to Gooch's link motion?

valve lead be kept equal when the eccentric is moved across aft for reversing purposes?

uld you shift the eccentric position in order to reverse the ion of revolution?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VI.

CONTINUED.

Can the valve lead be kept equal when the point of cut-off is varied by shifting the eccentric across the shaft or crank-axle?

At which end of the cylinder will the lead be greatest when the eccentric is shifted across the shaft from a point that is on the line of centers at the time that the crank-pin is on the line of centers?

How can this discrepancy be equalized?

Will such equalization exist for all points of cut-off?

If the eccentric is shifted across the shaft to vary the point of cut-off, should the eccentric hanger point of suspension be such as to give a greater amount of valve lead at the head end or at the crank end of the cylinder?

PART VI.

REVERSING GEARS.

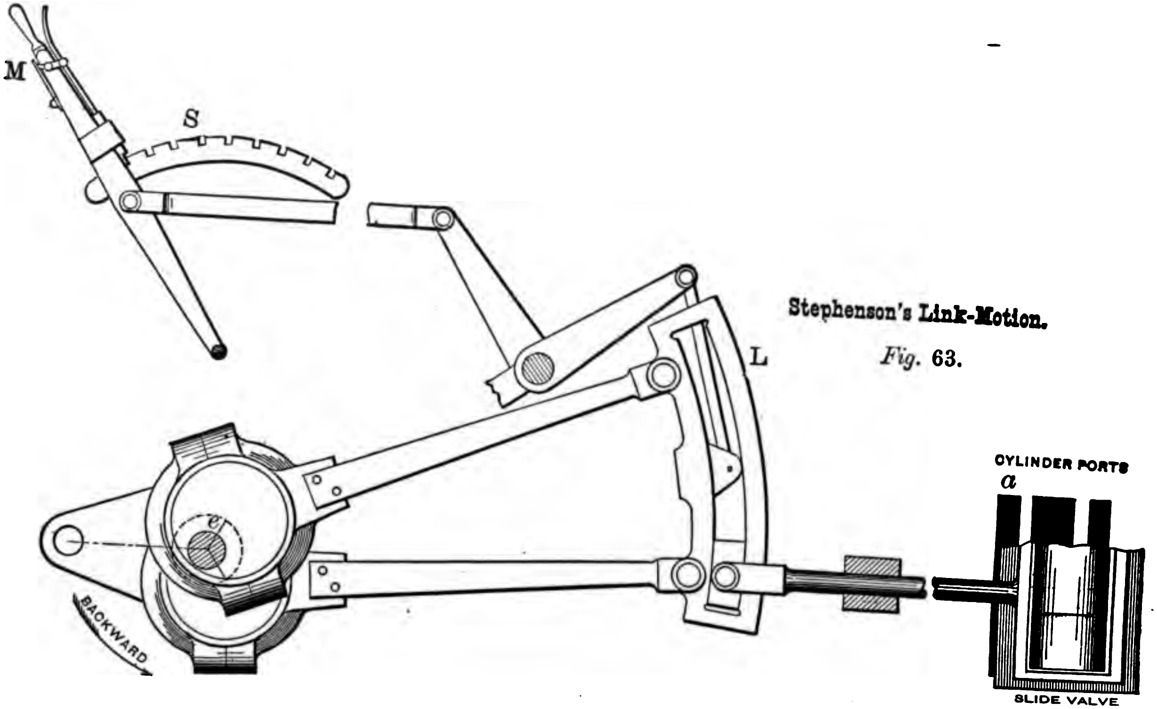
The methods employed to enable an engine to be reversed (i. e. run in either direction), may be classified as follows: first, by a link-motion, second, by moving the eccentric around the shaft, and third by shifting or swinging the eccentric across the crank-shaft.

Stephenson's Link-Motion is that most commonly employed.· It is constructed with open or crossed rods.

A Stephenson's Link-Motion with open Rods is shown in Fig. 63 and it is seen that the crank-pin being on the dead center furthest from the cylinder the rods connect straight to the link without crossing each other.

If we were to disconnect the rods R and connect the upper end of the link and the lower rod, to the upper end of the link, we should have a Stephenson's link-motion with crossed rods.

The Link L is in full Gear when the reversing lever M is in an end notch of the sector, thus in the figure the reversing lever M is in the backward end notch and the link is in full gear for the backward motion, and to bring it in full



Stephenson's **Link-Motion.**

Fig. 63.

gear forward motion, the lever would require to be placed in the end notch at the other end of the sector S.

When in Full Gear a Link-Motion opens the port the widest for admission, and the steam follows during the longest portion of the stroke.

In proportion as the lever is hooked up or moved towards the vertical position the amount of valve travel is reduced the point of cut-off occurs earlier, and the amount the port opens for the admission is less.

When the reversing lever is vertical or in the middle notch of the sector S, the link is in mid-gear, and the amount the port opens for the admission of steam, depends upon the construction of the link-motion.

In an Open Rod Link-Motion the amount of valve lead is increased, by shifting the link from full to mid-gear, whereas, in a crossed rod link-motion the valve lead is diminished by doing so.

When Starting an Engine having a link-motion, the link is put in full gear, and in the case of very large engines the link is moved for backward and forward gear, so as to let in the steam alternately on each side of the piston, so as to warm it and the cylinder before starting the engine. The cylinder cocks are opened so as to let the water from the steam, condensed in the cylinder, pass out before the engine is started.

GOOCH'S LINK MOTION.

In Gooch's motion, Fig. 64, the link vibrates on a fixed center, the saddle-pin being supported by an arm which is pivoted at its upper end *b*. The link-block is pivoted on a rod that is pivoted at Q to the end of the valve rod. In the figure the crank is supposed to be on the dead center furthest from the cylinder, and the link is so hung, that the link-block can be moved from end to end of the link-slot without imparting any motion to the valve rod.

The Valve Lead is Equal therefore for all points of cut-off and for both strokes because when the crank is on the other dead center, the link-block can again be moved from end to end of the link-slot without moving the valve.

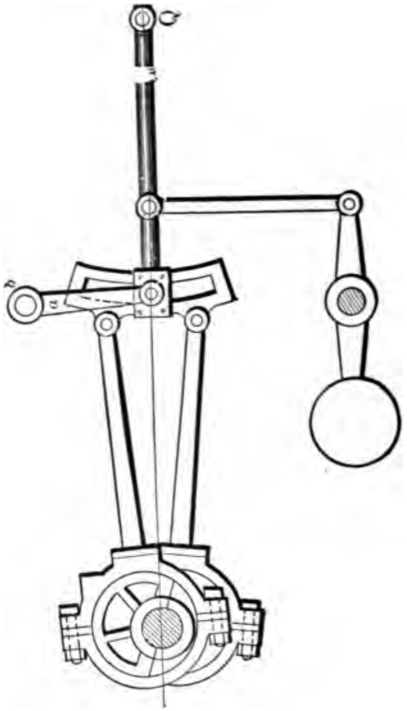


Fig. 64.

In the figure the link-block is shown in mid-gear, and it is obvious, that moving it along the line of centers will cause the valve to move in the opposite direction to what it would run in if the link-block were moved below the line of centers, and also that the further it is moved from the line of centers the more the valve travel will be, and the later the cut-off will occur.

The Objection of Gooch's Link-Motion is, that in proportion as the link-block is moved towards full gear (where the strain is the most on account of the valve having the most travel), the greater the angle of the link-block rod to the line of engine centers, and this puts a side strain on the valve rod, causing undue friction and wear to the bore of the valve rod gland.

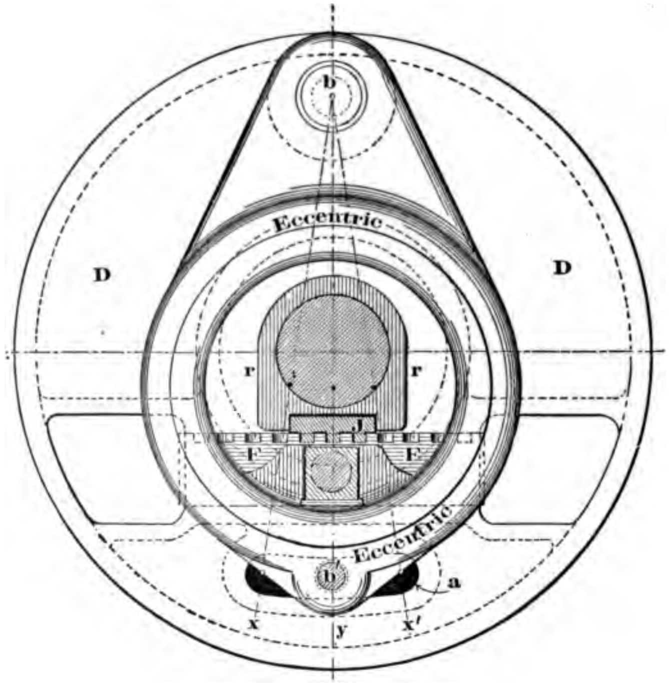
When the Reversing is Done by shifting the eccentric across the shaft the lead cannot be kept equal, but will, if the eccentric is swung from a pivot that is on the line of centers, when the crank is on a dead center, be greater at the head-end than at the crank-end of the cylinder. The discrepancy may, however, be equalized by swinging the eccentric from a pivot that is not on the line of centers at a time the crank is on a dead center.

But this Equalization will only exist at some one point in the eccentric position, or in other words, if the eccentric is shifted across the crank-shaft simply to reverse the engine, and not to vary the point of cut-off, it will naturally be moved, in reversing the engine across the shaft to a given and constant amount, and in this case, the pivot on which its hanger is hung may be so located with reference to the line of centers and the crank (the latter being on a dead center when the point of suspension of the eccentric-hanger is found), that the lead is equal for both the backward and forward gears.

But if the eccentric is shifted across the shaft to vary the point of cut-off as well as to reverse the direction of engine revolution, the lead cannot be kept equal.

It is better, in this case, to so locate the point of eccentric-hanger suspension as to let the lead be the most at the head-end cylinder port, because the piston travels fastest at that end of the cylinder, and therefore requires more lead, in order to cushion the piston.

A construction for shifting the eccentric across the shaft is shown in Fig. 65 in which D D is a disc having, at *d*, a pivot for the eccentric-hanger. The amount the throw-line of



End Elevation.

Fig. 65.

the eccentric must be shifted to reverse from full gear forwards to full gear backwards, is from the line *d x* to line *d x'*, and the shifting is done by two racks F and J, having teeth at an angle of 45° to their lengths. F is fast to the eccentric, and J is carried in a sleeve that slides along the shaft, and sliding it moves the eccentric across the shaft by reason of the teeth of one rack being at a right angle to those of the other.

It is obvious that the eccentric may be moved around the shaft in place of across it, the distance its throw-line requires to be moved being the same in either case.

To Shift an Eccentric so as to reverse the direction of engine revolution, all that is necessary is to place the crank on either dead center and measure the amount of valve lead. Then loosen the eccentric from the crank-shaft, and while the crank is stationary, move it around upon the shaft until it has opened the port full, and nearly close it again, leaving it open to the same amount as it was before the eccentric was moved, or in other words, open to the amount of the lead.

To Find how much the eccentric must be moved across the shaft to reverse the motion from full gear forward to full gear backward, we proceed as in Fig. 65*a* in which the diameter of the large dotted circle is equal to twice the throw of the eccentric and therefore represents the path of the eccentric center full size.

It also represents on a smaller scale the path of the crank-pin, which is shown on the dead center *a*. The dotted circle G G has a radius equal to the lap of the valve, and a line P P at a right angle to the line of engine centers, and just touching the circle G G, will give at X the position of the throw-line of the eccentric when the engine is to run in the direction of the arrow, and at X′ the eccentric position when the engine is to run in the opposite direction.

The line Y B in Fig. 65 corresponds to the line of centers in Fig. 65*a* and points X X′ to X X′ in that figure, and while the eccentric is being moved from X to the line of centers, the engine will move in the main direction, but the point of cut-off will be hastened.

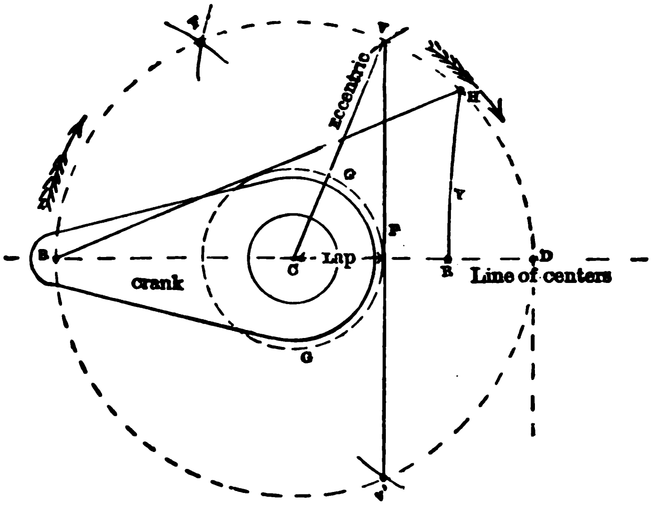


Fig. 65*a.*

After the eccentric has passed the line of centers, the point of cut-off will again be prolonged and the direction of engine revolution will be reversed.

———o:o———

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VII.

Is the linear motion given by an eccentric the same as that given by a crank-pin?

Make a rough sketch showing how to find the amount of steam lap necessary to cut off the steam at three-quarters of the piston-stroke, the valve having no lead.

Make a similar sketch allowing the valve to have ¼ inch lead.

Make a similar sketch showing how to find the position of the crank-pin when the port opens for the lead.

Make a rough sketch showing how to find when the cut-off will occur when the amount of lap is given.

What effect does giving a valve lead have upon the point of cut-off?

PART VII.

FINDING THE WORKING RESULTS GIVEN BY A VALVE.

Although Not Strictly within the line of duty of an engineer or engine driver, he is nevertheless sometimes called upon to find out how a valve of given proportions will dispose of the steam, or what proportions to give to a valve to accomplish certain results.

This is Easy Enough when either the travel of the valve or the amount of the lap, and the width of the port is given, but if the width of the port alone is given, and all the other elements are to be found, it becomes a more difficult problem.

An engineer, however, is rarely called upon to solve the question from this stand point, which properly belongs to the draughtsman or engine designer, and which is therefore fully treated in a work by the author of this work, and entitled, "Modern Steam Engines."

If the amount of valve travel is given, however, and the width of the port is known (as it generally is in cases that are presented to an engine driver), all the other elements may readily be found by the following constructions:

THE ECCENTRIC.

An Eccentric is the exact equivalent of a crank having the same amount of throw, as may be seen from Fig. 66, in which the outer dotted circle represents the path of the crank and the inner one the path of the center of the eccentric.

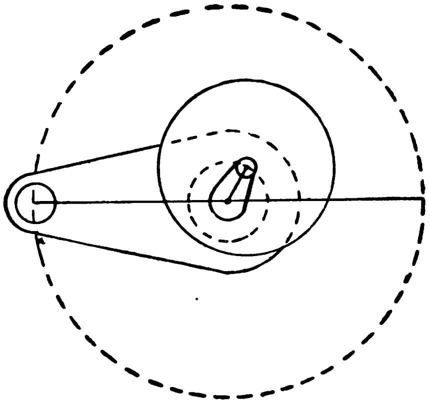


Fig. 66.

A small crank is marked in having the same throw as the eccentric has, and the motion given by this small crank is precisely the same as that given by the eccentric whose circumference is denoted by the circle.

Considering the Motion of both the crank and the eccentric, therefore, we may treat them precisely the same as two levers placed a certain distance apart, revolving upon the same center (the center of the crank-shaft), and represented by their throw-lines.

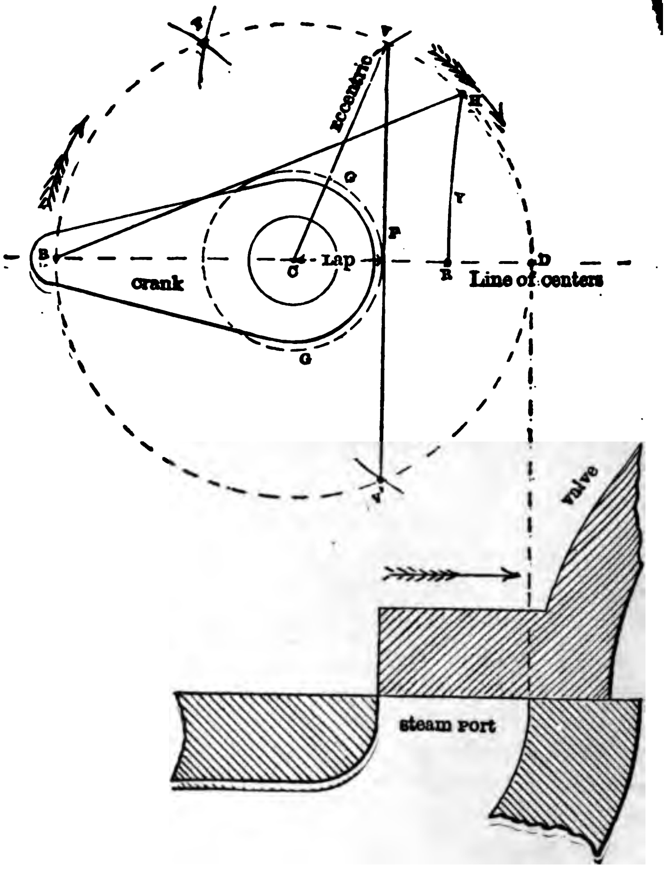


Fig. 67.

Diagram for Finding the Proportions of a Slide-Valve.

The Valve Travel and Point of Cut-Off Being Given to Find the required amount of lap there being no lead, draw a circle equal in diameter to the travel of the valve, or what is the same thing, equal to twice the throw of the eccentric, and draw the line of centers B D, Fig. 67; mark on the line of centers a point R, representing the position the piston is to be in at the time the cut-off is to take place.

Set a Pair of Compasses to represent the length of the connecting-rod on the same scale as the circle, B D represents the path of the crank, thus if the connecting-rod is three times the length of the stroke the compasses would be set to three times the diameter of the circle B D.

A straight line from B to D and passing through the center C of the crank will represent the line of centers of the engine, which must be prolonged to the right sufficiently to rest the compasses on it and draw the arc *y*, which will give at H the position of the crank when the piston is at R, and the cut-off is to occur.

We have thus found that the amount of circular path the crank will move through from the dead center to the point of cut-off is from B to H, and as the eccentric is fast upon the same shaft, it will in the same time, of course move through the same part of a circle.

One Half of its Motion will be to open, and one half to close the port, so that we may by means of the arcs at F get the point F, which is midway between B and H, and with the compasses set from B to F, mark from D the two arcs V and V′ whose distance apart will obviously be the same as from B to H.

Then from V to V′ draw the line P, and from this line to the center C of the crank-shaft is the amount of steam lap necessary for the valve, while from this line (P) to D, is the width of the steam-port.

The Proof of the Diagram is as follows;

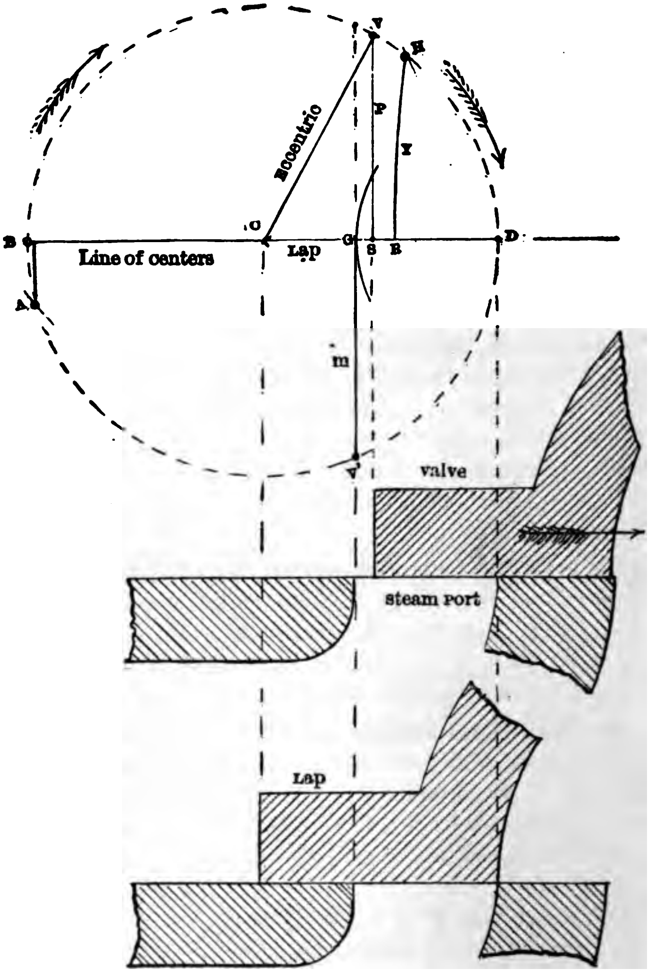

V
H
P
Y
Eccentric
C
B
Line of centers
Lap
G
S
E
D
A
m
V
valve
steam port
Lap

Fig. 68.

When the crank is on the dead center, the center of the eccentric is at V, its throw-line being represented by the line from V to C, and the valve is about to open the port as shown in the figure.

While the eccentric is moving from V to D, the valve will move in the direction of the arrow and will fully open the port, while the crank-pin will move from B to F.

Then, while the crank moves from F to H, the eccentric will have moved the valve to the position it occupies in the figure, having closed the port and effected the cut-off.

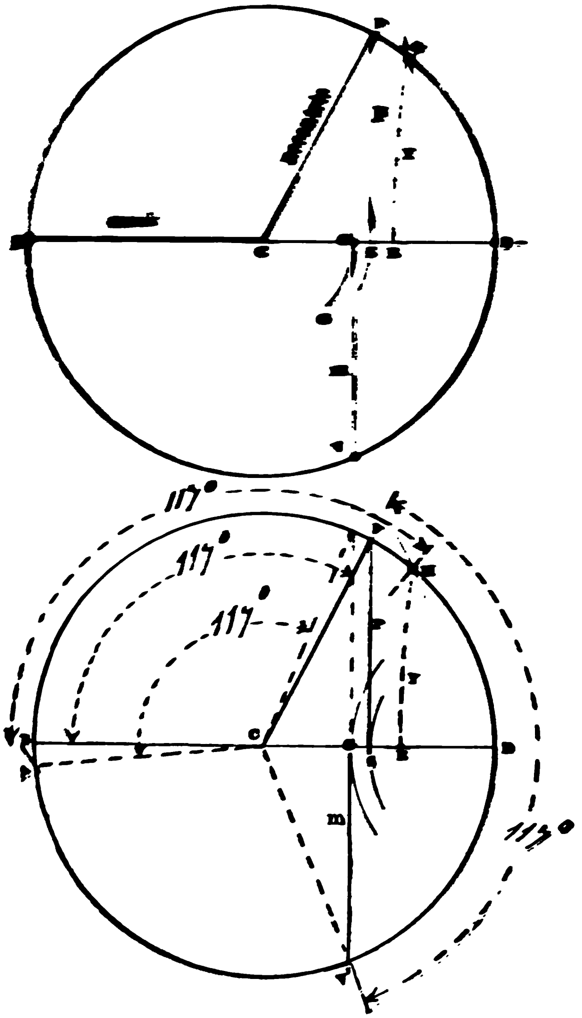
We have here found the amount of lap and the position of the eccentric necessary for a given point of cut-off when the latter is given in terms of the piston-stroke. If, however, the point of cut-off had been given in terms of the crank-pin position, we might find the required amount of lap at once, by simply drawing a line from the center B, the point to H where the crank-pin is to be when the cut-off occurs.

From this line we could then draw the dotted circle G, and just meeting the line *p*, which would give the eccentric position.

To find the piston position, the arc Y would require to be drawn by the same means as before.

If the Valve is to have Lead the diagram may be constructed as in Fig. 68, in which the circle has a diameter equal to the travel of the valve and the cut-off is to occur when the piston is at R and the crank at H.

When the valve is at the end of its travel, and has fully opened the port, the eccentric will be at D, hence from D we mark an arc G distant from D to an amount equal to the width of the steam-port, and at its lower end V′ is the position of the eccentric center at the point of cut-off. Then draw a line P which will give at V the position of the eccentric when the crank is on the dead center, and the valve is open to the amount of the lead. The lap is obviously the



Figs. 69 & 70.

distance from the center C of the crank-shaft to the arc G.

We Have Here Found all the points necessary except the point at which the valve will open the port for the lead, and this we may find by setting a pair of compasses to the radius B H (or to radius V V′, as both these radii are equal), and from V as a center, mark at A an arc, which will give the crank-pin position at the time the port first opens for the lead, or in other words, it will give the position. The proof of the construction is; that if we set the compasses to the distance between the crank-pin position on the dead center and the point of cut-off (or from B to H), we may apply the compasses to the points V V′, which represent the eccentric position when the port is opened to the amount of the lead, and when the cut-off occurs.

If the Point of Cut-off only is to be found, we mark from C, Fig. 69, an arc G representing the amount of valve lap and an arc S representing the lead. A line P gives the eccentric position when the crank is on the dead center at B, and a line *m* from G, gives at V′ the eccentric position at the point of cut-off. Then with the compasses set to the points V V′, we may mark from B an arc, locating at H the position of the crank at the point of cut-off, and from this with compasses set to represent the length of the connecting-rod on the same scale as the circle represents the path of the crank, we may, from a point on the line of centers, mark an arc Y giving at R the piston position at the point of cut-off.

When, therefore, the lap is given, we mark it from the center C of the crank-shaft, and find the other elements from it, whereas, when the lap is to be found, we mark the width of the port from the end D of the valve travel, and find the other elements from that.

A Proof of all the constructions is given in Fig. 70, in which the letters of reference correspond to those in the previous figures, and the positions of the parts are marked in degrees of angle.

To Find the Piston Position at the point of cut-off, measured in inches, of the piston-stroke it must be borne in mind, that as the circle B D represents the full travel of the valve, the diagram gives all the positions of the eccentric and valve full size, but that as it represents the crank path on a reduced scale, therefore we must multiply the measurement on the diagram by that scale.

Suppose for example, that the piston-stroke is 10 inches, and the valve travel 2½ inches, and the circle being 2½ inches in diameter, is when considered with relation to the eccentric motion, full size, but when considered with relation to the piston or crank motion, it is only ¼ the size, hence to find the piston position at the time of cut-off, we must multiply the distance, from B to R, by 4.

* * *

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VIII.

That are the circumstances that render the running of a locomotive more arduous than running a stationary engine?

What is the first thing to be done when getting a locomotive ready for a trip?

What is likely to have happened if the steam has condensed in the boiler?

What effect is likely to exist in the safety-valve?

What should be done before laying the fire?

How long should the wood burn before putting on coal?

How much coal would you feed at a time?

How deep would you make the first layer of coal?

What is "banking" a fire?

How would you start up a banked fire?

What examination of the engine would you make before starting on a trip?

What points would you move after having oiled the engine?

What points require examination when oiling the engine?

Where would you place tallow in oiling the engine, and for what purpose would you use it?

What would you do if steam was rising too rapidly?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VIII.

CONTINUED.

What is the first thing to do when the engine is to be started?

Where should the link be when starting the engine?

Why should the steam pressure be kept up, and what difference does it make in the consumption of the fuel?

Can steam be made quickest with a large or with a small quantity of water in the boiler?

Can a guage-glass alone be relied upon to give the true water level?

Which is the best, a constant or an intermittent boiler feed?

Which is the best, heavy firing at long intervals or light and frequent firing, and why?

When is a pump likely to show defectiveness?

What would you do if the cylinder cover got knocked out while on the road?

What would you do if the piston-rod got hot?

What if the piston-rod broke?

What if the crank-pin broke?

What if a wheel tire came off?

What if a driving wheel came ff?

What if a spring or spring hanger broke?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VIII.

CONTINUED.

In what position should the engine be placed when the axle-box wedges are to be adjusted for fit to the pedestals?

How would you find out whether or not the amount of clearance was equal at the two ends of the cylinder?

What is it that, as the engine wears, tends to alter the amount of the clearance?

Why is it best to have a constant boiler feed?

What is the object of charging one side of the fire at a time?

What would you do to keep up the fire after the steam was shut off?

How would you get the distance from center to center of the crank-pins when adjusting the axle-boxes and the side-rods, parallel-rods or coupling-rods as they are promiscuously termed?

Why are nuts more liable to come loose on locomotives than upon other engines?

What is the object of banking the fire?

Which causes the most clinker, a rapid or a slow combustion of the coal?

What is it a sign of when the safety-valve is steadily blowing off steam?

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VIII.

CONTINUED.

[illegible]

[illegible]

[illegible]

[illegible] *stroke?*

[illegible] *when adjusting the* [illegible]

[illegible]

[illegible] *equal at the* [illegible]

Make [illegible]

Does [illegible]

From [illegible]

What [illegible]

In what [illegible]
gear?

How would [illegible]

PART VIII.

LOCOMOTIVE RUNNING.

The Engineers Duty in running a locomotive is more arduous, and requires more watchfulness than any other engine running because of the peculiarities attending it. In the first place, the jolts and jars to which the engine is subject are liable to cause nuts, pins, etc., to come loose, and some of the parts to become disconnected and cause a break down of the engine.

This renders necessary a careful examination of the engine which should be made both before and after each trip.

In the second place we have that the amount of load the engine has to pull varies with every varying grade in the railroad track, and the variation is so great, that on some descending grades the engine may require no steam whatever, while on ascending grades the utmost power attainable from the engine may be required. In firing, feeding the pumps, oiling the parts, and determining the depth of water in the boiler, the grade and the length of each grade has an important bearing, and so has the weather, since it is clear that between the heat of summer and the blizzards of winter,

QUESTIONS WHOSE ANSWERS WILL BE LEARNED FROM PART VIII.

CONTINUED.

What if a tube bursted?

What if an eccentric slipped?

What if an axle box got hot?

What if a lifting link or saddle-pin broke?

In what position would you place the crank when adjusting the shoes or wedges of the axle boxes?

Why is this adjustment important?

What would you do to find out if the clearance was equal at the two ends of the cylinder?

Make a rough sketch of a locomotive link motion.

Does the wrong eccentric lead or follow the crank when the link is in full gear?

From what part of the engine is Joy's valve gear driven?

What is the object of the adjustable point in Joy's valve gear?

In what position should the crank be when adjusting a Joy valve gear?

How would you know whether the adjustment was correct or not?

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In what position should the crank be when adjusting a Joy gear?

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Before Laying the Fire the fire-bars and ash-pan should be cleared of ashes and clinkers, and the grate-bars tried with the shaking levers to see that the grates will shake properly. It should be seen that the tubes, etc., are clear of ashes.

In Laying a New Fire an ample supply of lighting material should be used, disposing it so that the fire will light evenly and not in spots, and a good layer of wood should be evenly distributed over the bars, the thinnest pieces being at the bottom as it will light easiest, and it is necessary to light the fire at the bottom so that the heat from the wood that is first lighted shall pass through that to be lighted.

The wood should be kept burning without coal until the lower stratum has ceased to blaze and covers the bars, while there is an even layer of blazing wood above it.

The quantity of coal to be fed at a time, and the depth of fire to be kept, depends upon the size of the coal, because the larger the coal the less it obstructs the draught, and the thicker the layer required in order to prevent currents of air from passing through without entering into combustion with the gasses from the coal.

If the coal is mixed containing large lumps they should be broken.

The first layer of coal should be enough to cover the fire to a depth of about two inches, which will permit of a good draught. This will get well alight while the wood is still servicable and a second layer may be applied of another two inches. The third feeding should be given with a view to have a greater depth of fire at the sides, than at the middle of the fire-box, because the cool sides of the box prevent perfect combustion, and currents of cold air are more apt to find their way through the sides than in the middle of the fire-box.

Banking a Fire consists of piling it up at the back half of the fire-box and covering it up with green coal, so that it may keep alight, and keep the boiler hot without increasing the steam pressure.

The air passing through the uncovered half of the fire-bars prevents rapid combustion and a dead fire is maintained.

In Starting up a Banked Fire the first thing to do is to clean it of ashes, clinker, etc., shaking up the bars to see that they will work properly. The fire is then spread evenly over the bars, and wood fed to enliven the fire and promote the draught.

The blown or blast pipe is then set going, and coal gradually fed a little at a time, evenly distributed, covering those parts the most where the fire burns through the most brightly.

A Steady Fire is better than one that is forced, because the combustion is more perfect and less clinker is formed, hence less cleaning will be necessary, and the fire done will not be kept open so long to let in cold air. This is important because a steady temperature in the fire-box promotes its durability, as well as giving an uniform boiler pressure. The strains placed before a fire-box by a fierce fire, suddenly cooled by a heavy charge of coal or of cold air from an open fire door are highly destructive.

Furthermore, the greatest economy of fuel is attained by keeping the boiler pressure up, and using the steam expansively by hooking up the links to shorten the point of cut-off.

A Safety-Valve steadily blowing off steam, whether the engine is running or not, is a sign of bad firing and wastefulness.

It is the Firemans duty to attend to the fire, but nevertheless a careful engineer will be as much interested in proper firing as in his own duties, and as the engieeer has more experience than the fireman he is warranted in exercising an ordinary supervision on the firing, which will be welcome to an earnest or ambitious fireman.

The Engineer should Examine with a wrench in hand the bolts and nuts about the trucks and axle boxes, as these are apt to become loose and come off on the road, a proper construction would remedy this defect almost entirely, and by a proper construction is under the more frequent emyloyment of split pins, colters, and other similar safety appliances now omitted for the sake of economy of manufacture.

Nothing in the future of the locomotive is more certain than improvement in this respect, and nothing is more urgently needed, as any engineer will become satisfied if he will gather up along a mile of ordinary railroad the nuts and washers that lay along the track.

The Eccentric-Straps and the pins in the link-motion require an examination, which may be done while oiling the parts of the engine.

The Oiling requires careful attention; first the cups themselves sometimes become loose, an argument in favor of having, wherever possible, the cups solid on the parts, as done in European practice.

Oil Holes are apt to get choked by gumming, which is that the oil in time forms into a brown gumming substance that fills the oil hole. Perfect lubrication does not imply wasteful lubrication by any means, but a wasteful use of oil is probably less expensive than insufficient lubrication.

A Thorough Engineer will use no more oil than is necessary, he will leave nothing to conjection or chance, but know from personal inspection that his engine is in complete working order, and to this end the lubrication of the working parts is a vital element.

After having oiled the eccentic-straps the link-motion and the reversing gear beneath the engine, the reversing lever and the parts above the frame must be oiled, and the reversing lever moved back and forth several times from end to end of the sector, or quadrant, so as to distribute the oil throughout the joints and working surfaces.

The Axle Boxes require careful attention in oiling. In English practice tallow is packed in the corners of the cavities of the top of the box, so that if the box should begin to heat the tallow will melt and afford extra lubrication with a heavier lubricant than usual, which will often stop the heating.

The connecting and coupling rods then require attention, the cups being filled, and the lubrication adjusted.

When steam is up the guage glass should be blown through again, and it will be found that the water stands higher in the glass than it did before the boiler was under pressure.

The packing of the piston and of the pump glands, if the engine has pumps, should be known to be properly set up, bearing in mind that a leaky pump gland lets air into the pump and impairs its action.

The sand box should contain dry sand as wet sand will not feed properly.

If steam is raising too rapidly close the lower damper to reduce the consumption of fuel and save blowing off steam through the safety-valve, which should always be avoided as much as possible.

Before starting the engine, open the cylinder cocks and keep them open until the sound discloses that dry steam and not steam and water is issuing.

Open the throttle enough to start the engine early and not with a pump, and be prepared to shut off steam instantly if a blow in any part of the engine should indicate an obstruction to its working.

In starting a train the reversing lever is put in the end forward notch and the cylinder cocks opened. Then the throttle is opened a little at first, so as to avoid starting with a violent shock that might break the couplings.

If in starting (or in ascending gradients), the wheels are formed to slip, the sand lever should be operated, a slight sprinkling of sand serving better than a heavy one. If the sand is damp it will fall in lumps and not distribute evenly as it should do, while at the same time a great deal more and will be found necessary.

When the Train is fairly under way the aim should be to maintain full boiler pressure, so as to keep up the required speed with the links hooked up to work the steam as expansively as possible, bearing in mind that the higher up the links are hooked the more expansively the steam is used, and that therefore less steam is used to do the work and the boiler pressure can be kept up easier.

To understand this clearly, let it be supposed that the steam pressure in the boiler is 90 lbs per square inch, and that the piston area is 400 inches, and the total pressure impelling the piston will be 36,000 lbs. if this follows the piston for 22 inches the power becomes 792,000 inch lbs per stroke.

Now suppose the pressure is 150 lbs per square inch, and this multiplied by the piston area (400) gives 60,000 lbs impelling the piston, and this would require to follow the piston but 13 inches in order to give 792,000 inch pounds. In the one case we have 22 inches, and in the other 13 inches of the cylinder to fill with steam. Of course it will take more fuel under the heat of firing to keep the pressure up to the 150 lbs, but on the other hand, when the steam is cut-off in the cylinder there will be 160 lbs per square inch in it, and all the work that this does in expanding is gain during the rest of the stroke, so that the required amount of power would be obtained by cutting off earlier than at 13 inches

The water should, under ordinary conditions, be kept at an uniform level in the boiler. Steam can of course be made quicker with a small than with a large quantity of water, but the smaller the quantity of water the more the steam pressure is liable to fluctuate, and the closer the firing must be attended to.

Furthermore, the More Water there is in the Boiler the greater the safety, because the longer the boiler can go without feeding and if the pumps or injectors, as the case may be, should act imperfectly, there is more time to get them working properly.

In Testing the Water Level the gauge-glass alone is not to be entirely depended upon, hence the gauge-cocks should be opened. The water should not be allowed to go below the middle gauge-cock.

It is obvious that when the water is below a certain gauge cock, the gauge-glass only can give any information as to how far it is below it, hence it must be used for this purpose.

When Using it it should be blown through by opening its lower cock, and if there is any doubt about its showing the proper water level it should be blown through two or three times, watching the level of the water in the glass at each trial.

A Constant Boiler Feeding is the best, as it is more conducive to a uniform boiler pressure and temperature.

The Fire should be fed in small charges, the fire door being kept open as little as possible, because a high temperature in the fire-box is necessary to perfect combustion. If heavy charges of coal are given at once, then for some time the fire-box will be cooled, and then as the fire burns through a fierce heat will be generated. This alternate heating and cooling is very destructive to the fire-box and the tubes, as it causes an expansion and contraction that racks the joints and seams.

There are Several Ways of firing, each having its advocate upon the following points, however there is no dispute. First a slow combustion is the most perfect because it produces less clinker, which saves fuel and also saves a large amount of fire cleaning and therefore of admission of cold air to the fire-box. A high temperature is necessary to combustion and the temperature of the fuel is most difficult to keep up at the sides of the fire-box.

By Light and Frequent firing the bright fire will never be covered up, hence the temperature will be maintained. This favors an even distribution over a large surface of the fire of each shovelful of coal. But if at any point the draught is lifting the fire, and small bright pieces of fire are lifting up, it is an evidence that the fire is thinnest there or else that the bars are cleanest there. In either case an extra amount of coal is required at that spot.

Some engineers will charge one side of the fire-box lightly and then the other, this being done so as to keep up the temperature in the fire-box. Others will fire first the front and then the back of the box, which answers the same purpose, but in no case should the charge be heavy.

A fireman may become so accustomed to the road and his engine, that under some conditions he may fire when he reaches certain points on the road, regulating it like clockwork.

On a Trip from Philadelphia to Reading on an engine having a Wooten fire-box (whose especial feature is a large fire-box, which enables slow combustion), the firing was conducted as follows:

The fire was not fed or touched until just before reaching Bridgeport, 18 miles from Philadelphia, when a thin layer of coal was spread evenly on the fire. Eleven miles were then made without opening the fire door, the next firing taking place just before reaching Phœnixville.

Ten Miles were run before the next firing, which occurred just before arriving at Pottstown.

The next firing occurred at Bordenboro three miles from Pottstown. The remaining 8 miles were made without firing. The steam pressure did not vary more than 10 lbs per square inch during the trip.

On a Trip from New York to Philadelphia by the lightning express train the firing was conducted as follows:

The coal was anthracite and in lumps from 5 to 7 inches in diameter, at one end it reached up to the level of the fire door while at the tube-plate end of the fire-box it was about 6 inches deep.

The Grate-bars were constructed to shake in three sections, and shaking the bars to clear out the fire caused it to feed forward of itself, and the combustion of the coal caused it to break up into lumps about 2 inches in diameter at the tube-plate, where the fire was much brighter than at the fire door end. The steam pressure varied about 10 lbs. during the trip.

We Now Come to the best times to fire, to feed and to oil the valves, and this depends on the level of the road.

On a level road these matters could be attended to with regularity, but as the engine has most work to do in ascending inclines, it is necessary to prepare for such emergencies.

First by having a good fire prepared, so that the fire door may be kept closed as much as possible while the engine is ascending, second, by having plenty of water in the boiler so as to keep steam, without feeding any more than possible, when the engine is calling for more steam by reason of the reversing lever being put over towards full gear.

The speed is kept well up before reaching the incline, and the reversing lever moved forward a notch or two at a time to maintain the speed, while at the same time moving the sand lever to feed the sand as soon as the engine speed shows signs of reducing.

PUMPS AND INJECTORS.

A Defective Pump is likely to show its defectiveness when the engine is running the fastest, because the water is not drawn fast enough to follow the pump plunger. The injector therefore is more to be relied upon for fast speeds.

If the engine has both a pump and an injector the pump may be used for ordinary feeding, and the injector used to supplement the pump in case of deficiency.

When steam is shut off the draught of the fire is reduced, hence the water pumped into the boiler has an increased effect in reducing the pressure. This may be compensated for by starting the blower to keep up the draught.

But the boiler feed should be regulated to render unnecessary heavy feeding with the steam shut off. Another point to be considered is that the injector increases the temperature of the feed water, whereas the pump does not, hence the injector is preferable when the pressure is low, or should heavy feeding become necessary.

ACCIDENTS ON THE ROAD.

The Accidents to which the locomotive is most liable when running upon the road, and the course to be pursued by the engineer to enable him to take the engine to the depot or complete the trip, are as follows:

Knocking Out the Front Cylinder Head or Cover.

This arises from various causes, such as a breakage of a connecting-rod strap, or of a piston-rod or cross-head. It is the practice of some locomotive builders to cut in the cylinder-cover flange a small groove close to the part that fits the cylinder-bore, so that the cover shall break out in the form of a disk, leaving the cover, flange, bolts, and nuts intact, and dimishing the liability to break the cylinder itself as well as the cover

The Provisional Remedy for this accident is to take off the connecting-rod (on the side of the broken cover) and also the valve motion, either at the rock-shaft arm or by taking down the eccentric-rod straps. Then place the valve in the center of its travel so that it shall cover and enclose both the cylinder steam-ports and leave the exhaust-port open. Then pinch the back toward the cars as far as possible and go ahead with the other cylinder.

Heating of Piston-Rods. This the engineer can often discover by sight, or by smelling it from the cab. The remedy is to stop the engine and slack back the gland until the steam from the engine cylinder leaks freely through the packing. Then apply a little extra lubrication or water while *running slowly.*

If the Piston-Rod Breaks, but does not knock out the cylinder-head or cover, pursue the same course as directed for breaking the cylinder-cover, taking the additional precaution to block the piston, which may be done by fitting pieces of wood between the guide-bars, making the pieces long enough to fit between the cross-head and guide-yoke.

The cylinder or waste-water cocks on the side of the accident must also be opened, to prevent any leakage of steam past the slide-valve from getting into the cylinder and driving the piston against the cylinder-cover, and breaking the cylinder-cover or even the cylinder itself.

If the Piston-Rod Breaks From the Cross-Head, it is safest to remove it from the cylinder, though this is unnecessary, if it be securely blocked, against the cylinder-head so that it cannot move, though steam may leak in on either side of it.

The Breakage of Crank-Pins is a somewhat trequent accident, but seldom takes place on both sides of the engine at once.

The Remedy is to take off all the parallel or coupling-rods. and if it is the crank-pin on the driving-wheels which breaks, take off the connecting-rod also and securely block the cross-head, disconnecting the valve motion as before directed, and opening the cylinder waste-water cocks. In the case of this accident occurring, it is absolutely essential to take off the parallel rods on both sides of the engine, or otherwise the crank-pins on the other side are apt to break.

Thorwing off a Wheel-Tire. In this case the best plan is to block the tireless wheel entirely clear of the track, which may be done by putting a block of wood into the oil cellar of the driving-box, and then tow the engine to the repair shop; for if the engine is run to the shop, and the wheel touches the rail, it will impair its diameter for the proper size of tire.

Throwing Off a Driving Wheel. This is not a common accident, but nevertheless, it sometimes occurs; they break usually just outside of the driving-axle box. In this case take out the driving-box and fit in its place a block of wood affording journal bearing for the axle. Let this block rest on the pedestal cap, holding the axle up in the center of the pedestal. Then secure the piston and disconnect the valve gearing and open the cylinder cocks as before, and the engine can be run *slowly* to the repair-shop without danger of further accident, or, if convenient, it can be towed by another engine.

Breaking a Spring or Spring-Hanger. Lift the engine with the jacks until the driving-wheel axle-box is about in the center of the pedestal, and put any convenient piece of iron across the top of the driving-axle box and between it and the engine frame, thus taking the weight of the engine on the frame instead of on the spring. Place also a block of iron between the end of the equalizing bar and the top of the engine frame, so as to prevent the movement of the equalizing bar and to allow the spring at the other end of the equalizing bar to operate without moving the said bar. every engineer should carry in his tool box pieces of metal suitable for this purpose because this is a frequent accident It does not, however, materially affect the working of the engine, and should not delay a train more than a few minutes.

Bursted Flues and Tubes. These are usually plugged by tapering a piece of pine wood and driving it into the bursted tube by means of an iron bar. Taper iron plugs are often carried, and then driven into the end of the tube after the wooden one has been driven in. To enable this job to be done, it is necessary to thickly cover the fire with green coal, which operates to cool the tubes and prevent the loss of the water in the boiler. Sometimes careful engineers prepare for use pine plugs turned slightly taper and a little slack for the inside of the tube. In case of leak, this plug is inserted in the flue, and driven along it until it covers the fracture, the expansion due to its saturation causing it to become locked in the tube.

Slipping of Eccentrics. Place the reverse lever in the forward notch of the sector. Place the crank on its forward dead center, as near as can be judged by the eye, and loosen the set-screw of the forward eccentric, that is to say, the eccentric which connects to the upper end of the link. Move that eccentric round upon the axle until the slide-valve leaves the steam-port at the front end of the cylinder open to the amount of required valve lead. In moving the eccentric round upon the shaft, move it in the direction in which it will rotate when the engine is running forward, so as to allow for and take up any lost motion there may be in the eccentric straps, in the eccentric rod-eyes and bolts, and in the other working parts of the valve-gear; for if the eccentric was moved backward, all such lost motion would operate to vitiate the set of the valve. The eccentric being placed as directed, fastens its set-screw securely.

If the Backward Eccentric is the Loose One, throw the reverse lever to the backward notch of the sector, lifting the link up so that the eccentric connected to the lower end of the link may be approximately adjusted by moving it around upon the axle in the direction in which it will rotate when the engine is running backward, until the back cylinder port is open to the amount of the valve lead. Another very ready plan of temporarily adjusting the eccentrics, is as follows: Place the reverse lever in the end notch forward, and place the engine-crank or driving crank-pin as near on a dead-center as the eye will direct, and open both the cylinder waste-water cocks. Then disconnect the slide-valve spindle from the rocker-arm, and move the slide-valve spindle until the opening of the cylinder steam-port, corresponding to the end of the cylinder at which the piston stands, will be shown by steam blowing through the waste-water cock at that end of the cylinder; the throttle-valve being opened but a trifle, to allow a small steam supply to enter the steam-chest and cylinder, for if much steam is admitted, it may pass through a leak in the piston and blow through both the waste-water cylinder cocks.

The Position of the Valve Being Thus Determined the eccentric must be moved upon the driving-axle until the valve-spindle will connect with the rocker-arm without being moved, or moving the valve at all.

Hot Axle-boxes. If not convenient to reduce the speed of the engine, or if that and free lubrication do not cool the box, a plentiful supply of cold water should be administered, it being well to have at hand a small hose-pipe, by means of which water from the tender-tank can be used. If the brasses have Babbitt-metal in them and it should melt, it is better, if possible, to cool the axle-box while the engine is moving, which will injure the journal less than if the journal is stopped to cool the box, because in the latter case the brass or box is apt to become soldered to the journal of the axle, and when the engine is again started, the cutting or abrasion will recommence with extreme violence.

Breaking a Lifting-Link or the Saddle-Pin that connects the slot-link to the reverse shaft. Cut a piece of wood and tie it into the slot of the link over the link-block or die, making it of a length to keep the link in the position for hauling the train. Then fasten another piece of wood in the link-slot beneath the sliding-block or die, thus securing that die in the proper position for the engine to go ahead. In this case, the engineer must be careful in stopping, as he can not reverse the engine on the crippled side.

Secondary Accidents are Almost sure to Occur if a disconnected piston is not securely blocked in the cylinder, or from blocking the piston aright and attempting to let the slide-valve run, or from attempting to run with the parallel rods on one side only disconnected. There are numerous accidents, which only common sense and a familiarity with the locomotive can provide a temporary remedy for, but those here enumerated are by far the most common.

ADJUSTING THE PARTS OF A LOCOMOTIVE.

When the Wedges of the axle-boxes are to be adjusted for fit to the pedestal shoes the engine should be moved until the coupling-rods on one side of the engine are in line with the piston-rod, because in this position the rod will, to a certain extent, act as a guide in keeping the axles parallel to each other, and at a right angle to the line of engine centers.

Bear in Mind that the distance from the center to center of axle-boxes must be the same as the distance from center to center of the crank-pins, and that when the coupling or side rods are in line with the piston-rod they act to resist the axle boxes from being set up too close together.

The Importance of a proper adjustment of the axle-

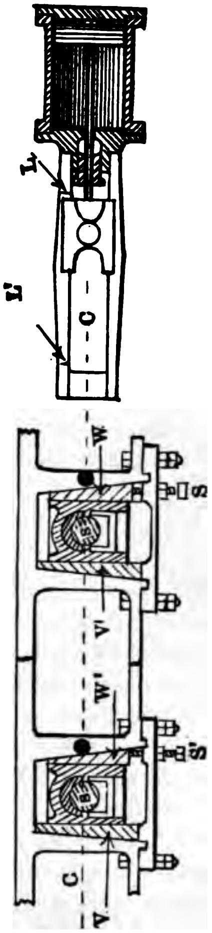


Fig. 71.

Adjusting the Parts of a Locomotive: Position for the Crank-Pin when setting up the Pedestal Shoes or Wedges.

boxes, coupling-boxes, and connecting-rods cannot be over estimated, and it is necessary therefore, to explain it thoroughly. In Fig. 71 then *s s* represent two wheel axles whose boxes are between the shoes V V,′ at S S′ are the wedges for setting up the the shoes or wedges *w* and *w′* respectively. The axles are shown on the line of centers C C of the engine the piston being at the head-end of the cylinder, and the crank-pins on the line of centers as denoted by the small black circles. The wedges W and W′ are shorter than the leg of the pedestal so that they may be set up by the set screw S and S′ and take up the wear.

In Some Engines the wedges V and V′ are also shorter for the same purpose. Now it is clear that setting up the screws S and S′ will move the axles *s s′* to the left, and this will alter the clearance between the piston when it is at the end of the stroke, and the cylinder-cover.

It is clear that the distance between the centers of the two axles must be the same as the distance between the centers of the two crank-pins, or else the frame will be subjected to a great strain, tending to break the crank-pins and the side rods.

In Order to Keep the clearance equal and to know when it is equal, it is necessary, at some time when the cylinrder-cover at the head-end is off, to disconnect the connecting-rod and push the piston clear up against the left-hand cylinder-cover, and from the cross-head as a guide make on the side of the guide a line L′. Then put on the cylinder-cover at the head-end and push the piston up againit it and mark a line L. Then when the connecting-rod is put on again the wheels may be moved around if the engine is jacked up, or if not the engine may be moved along the rails with a pinch-bar and the clearance will be equal when the cross-head (at the ends of the stroke) comes within an equal distance of the respective lines L′ L when the crank is on the dead centers, and it is well to adjust the wedges W and W′ so that the cross-head does travel within an equal distance, and mark on the guide-bar two more lines, one at each end of the bar.

These Lines are a Permanent Guide in setting up the shoes or wedges, and lining up the connecting-rods and coupling or side rods, because it is clear that from the method employed in marking them the distance between the end of the cross-head, when at the end of its stroke, and the line L, and that between the face of the piston and the cylinder-cover will be equal.

A Proper Adjustment, therefore, should be made as follows: The piston should be at the end of its stroke, the crank-pins being on the line of centers.

Screw S should be operated to set up the wedge W, taking up the wear of the sides of the box, and bringing the edge of the cross-head the proper distance from the line L. The connecting-rod brasses should then be set up to fit the pins, and the screw S′ operated to set up wedge W′ to have easy contact with the side of its axle-box. If, however, there has been so much wear on the axle-boxes that they are still too loose between the wedges, both wedges may be set up to take up this wear, since it is more important to have the axle-boxes a proper fit between the wedges than it is to maintain an exactly equal amount of clearance at each end of the cylinder.

The Engine will then be in Proper Tram on this side, or, in other words, the distance from the center to center of the crank-pins will be the same as that from center to center of the axles.

On the other side of the Engine the process is the same, the engine being moved until the crank-pins are on the line of centers C C and the wedges set up according to the lines.

LOCOMOTIVE LINK MOTION.

The Construction of a Locomotive Link Motion may be understood from Fig. 72, in which the crank is on the dead center at B.

The forward eccentric is shown at F, its throw-line being shown at *f*.

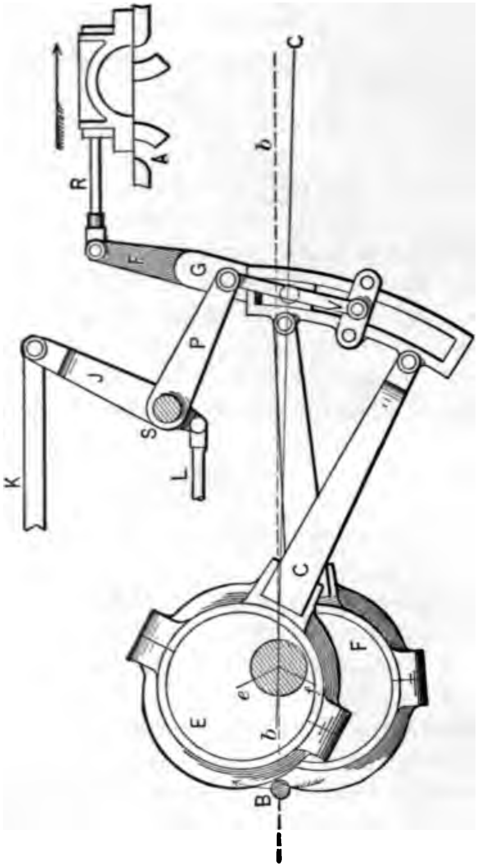


Fig. 72.

At E is the backward eccentric whose throw-line is sh
at *e*. The saddle-pin is shown at V. A suspension link

cting it to arm *p* of the tumbling-shaft S, whose upper arm nnects to the rod K from the reverse lever.

B *b* is the line of centers of the engine. F the rock-shaft hose center is at C, and rod R is the valve rod. The valve shown to have opened the port A to the amount of the ad.

As the link is down to its lowest position it is in full gear.

In Some Engines the end of the lower rocker-arm comes elow the line of centers B *b*, thus in the figure it comes own to a line C C, and this being the case the rocker-shaft rms are not in line with each other, the lower one having hat is termed an off-set.

It Will Be Seen that as the eccentric F is the one that in line with the lower end of the rock-shaft and of the link-ock (which is pivoted on the lower end of the rock-shaft), erefore it is the acting eccentric or that which is acting ect on the rock-shaft. When the link-motion is in full r the action is almost precisely the same as though no k motion was used, or in other words the eccentric-rod t is furthest from the line of centers of the engine has rcely any influence upon the valve-motion.

The Acting Eccentric is when the link is placed in full r, that which follows the crank in the path of revolution. us in the figure the link being in full forward gear, the nk-pin B will move in the direction of the arrow, and the entric F which follows the crank is the acting eccentric.

If we were to loosen this eccentric and turn it upon the ft the valve would be moved correspondingly, but if we re to loosen eccentric E, we might move it around the ft considerably, and it would produce but a slight motion the valve.

In Proportion As the link is hooked up, however, both entrics act on the valve, so that when the link is in mid- r the eccentrics have an equal effect in operating the valve. If the link is moved to full gear backwards, the centric *e* will have its rod brought up to the line of cent and will become the acting eccentric, and as the crank revolve in the opposite direction to the arrow, therefore centric *e* will follow the crank.

JOY'S VALVE-GEAR FOR LOCOMOTIVES.

Joy's Valve-gear gives the engineer very little trouble, because it dispenses with the eccentrics. Its construction is shown in Fig. 73, in which R is a section of the connecting rod, which gives motion to an arm A pivoted at its outer end to a rod T whose outer arm is pivoted to a fixed joint. Arm A operates a lever L whose other end operates the valve-spindle. On the rigid guide is a block to which one end of the suspension link or link-hanger is pivoted, the other end being pivoted to the lever L.

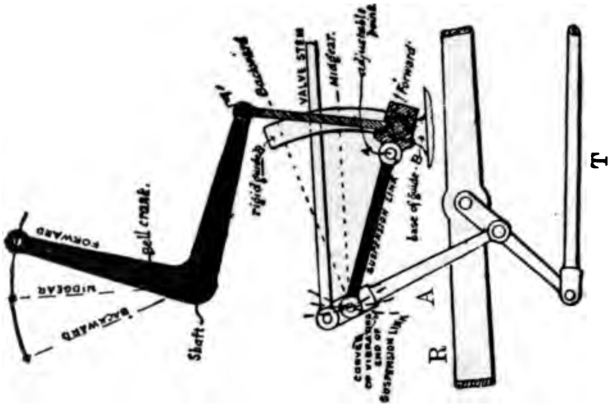


Fig. 73.

Fig. 74 represents a similar construction, except that the adjustable point, which is all that the engine driver needs to ern himself with, is in the application at opposite ends e suspension-link.

he application shown in Fig. 74 is for confined situations.

y Means of the adjustable point, the length of the pension-link can be altered and the lead adjusted.

The parts are shown in the position they would occupy en the crank was on the dead center, the pin at the left-and end of the suspension-link being the center from which the curve of the rigid guide is struck, hence supposing the engine to be at rest with the valve open to the amount of the lead, then the tumbling-shaft can be operated to move the guide-block from end to end of the guide without altering the lead.

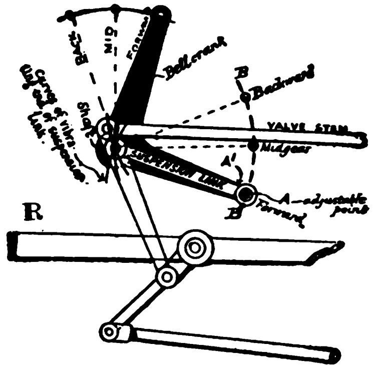


Fig. 74.

But if the Length of Suspension-Link be altered, this will no longer be the case, and the lead will alter as the block is moved up the fixed guide to alter the point of cut-off.

Obviously Then in Adjusting the positions of the parts the crank must be placed on the dead center, and the adjustable point so set that the valve will not be moved, if the block be moved from the end of the fixed guide.

PART IX.

CONDENSING ENGINES.

A Condensing Engine is one in which the exhaust steam is condensed, forming a partial vacuum on the exhaust side of the piston, which is done by either a jet or a surface condenser.

The Action of a Common or jet condenser may be understood from Fig. 79, in which the pipe E conveys the steam from the engine cylinder to the condenser, into which a jet of water is injected.

The Water falls upon perforated plates, which sub-divides it, thus bringing it into intimate contact with the steam, and rapidly condensing it.

The Water of Condensation and the injection water mingle at F and enter the foot of the condenser at D.

The foot valves are shown at V and V′, the former being open and the latter closed.

The pump bucket P is on the drawing stroke, while bucket P′ is descending, hence the water is passing through it to its upper side, its delivery valve being at *c*′ and the discharge pipe at H.

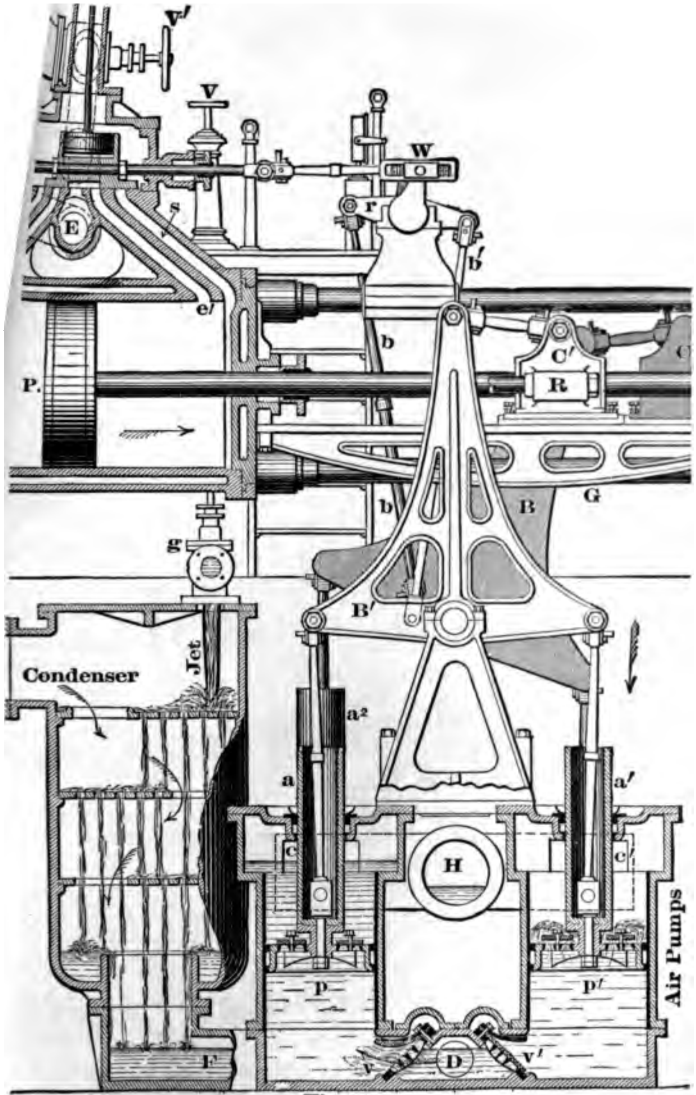

V′
V
W
r
s
E
b′
e′
b
C′
C
R
P.
G
B
b
g
B′
Jet
Condenser
a²
a
a′
c
c
H
Air Pumps
p
p′
D
v
v′
F

Fig. 75.

The Action of a Surface Condenser may be understood from Figs. 76 and 77. A beam A receiving motion from the engine cross-head works the bucket air pump and the circulating pump. The condenser C has two compartments and is filled with thin brass tubes through which the circulating or condensing water passes, first through one compartment and returning through the other. The steam fills the body of the condenser, and the products of condensation is pumped out by the bucket air pump which is shown in section.

In Some Engines Used About Harbors what is called a pipe condenser is used. The exhaust steam passes into a pipe that passes out at the side of the vessel, extends around the hull, and enters at the other side, so that the sea water serves for the condensing water, all that is necessary, therefore, is an air pump to draw out and discharge the air and gases from the pipe.

The Simplest Form of condensing engine is represented in the Davy Safety Engine *Fig.* 77*a.* in which the steam is generated up to atmospheric pressure, and is condensed to form a vacuum on one side of the piston, which is driven by the atmospheric pressure on its other side.

The Boiler is of cast-iron the part above and back of the furnace being cast in partitions, which serves the purpose of flues, giving the necessary heating surface, and which are not likely to be burned out or destroyed even if the boiler was fired without water.

No Safety-Valve is used, but a hole of large diameter covered by a plug laid loosely over it, prevents the accumulation of more than one-quarter of a pound gauge pressure. Ordinarily the pressure in the boiler is just sensibly less than that of the surrounding atmosphere, so that the plug is held down by the pressure of the latter. Practically, however, the internal and external pressures are balanced, so there is

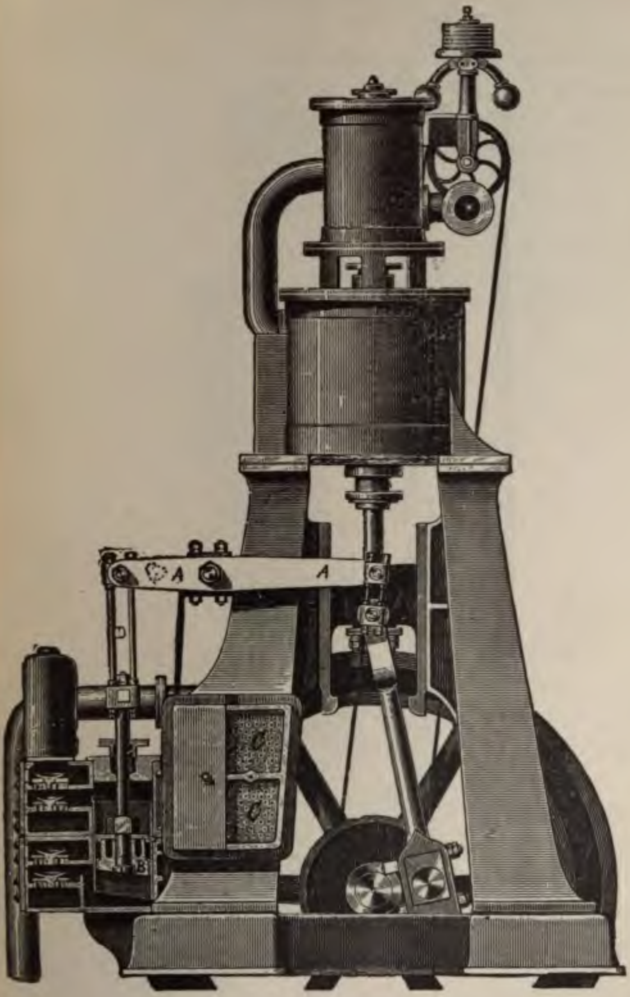


Fig. 76.

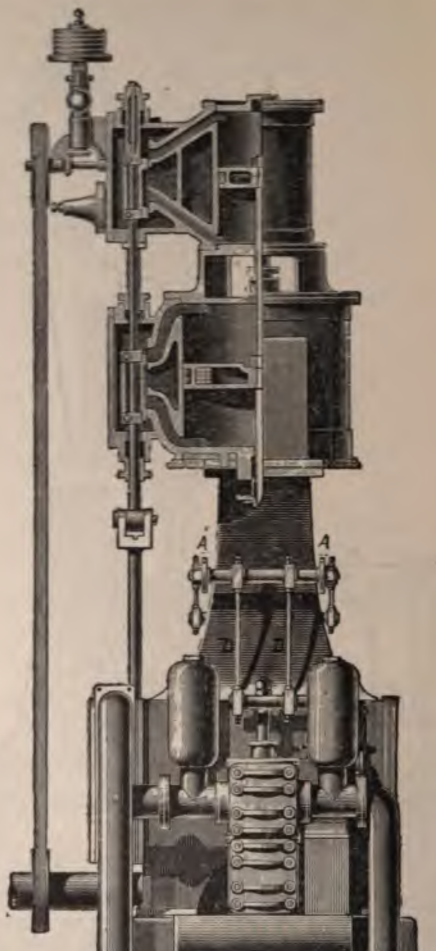


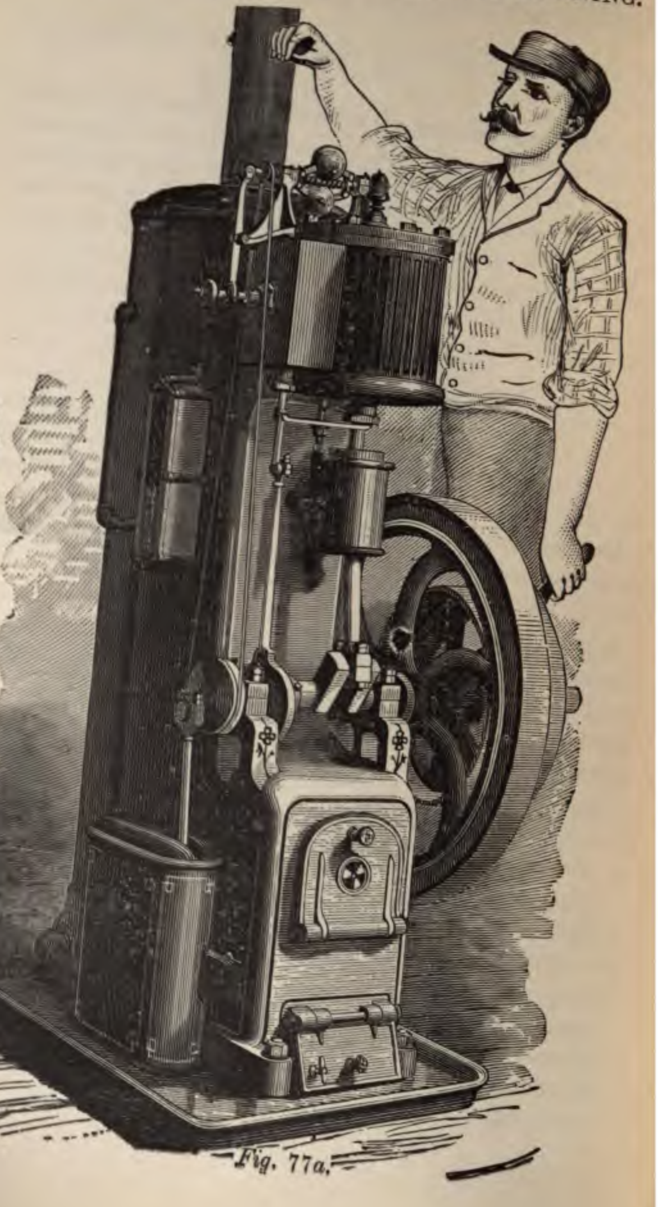
Fig. 77.

no pressure whatever tending to either burst or collapse the boiler.

The Surface Condenser is a casting open at the top, and provided with tubes in which the exhaust steam is condensed the water and air being removed by a single-acting air pump, of the plunger type. The top of the condenser is above the water level in the boiler, and the over flow from the condenser is at the top. The small head of water in the condenser (above the water level in the boiler), is utilized for feeding the boiler as follows: Connection is made between the top of the condenser and the water space in the boiler, by means of a small pipe. In this pipe is a cock, controlled by a float in the boiler. When the water falls in the boiler the cock is opened, the water running in by gravity. When the water rises the cock is closed. The water level is thus automatically maintained without the use of a pump, or any attention from the attendant. A glass panel in the side of the boiler provides for observing the water level.

The Condensing Water may be taken direct from the service pumps in cities, or, where this is not practicable, a small pump driven by the engine may be used for circulating the water. When the engine is used for pumping water, the water may be passed through the condenser. When water is scarce it may be used over and over, by standing long enough to cool: or the condenser may be located directly in a tank of water.

The Engine is double acting, with diameter of cylinder sufficient to give the rated power at a mean effective pressure of eight or ten pounds, which is easily maintained by the air pump. The cylinder is brass bushed, and the piston is of brass, no lubrication being required. The cylinder is steam jacketed around the body and at the ends. In general construction the engine does not differ materially from any small engine.



The Davy Condensing Engine.

Fig. 77a.

PART X.

THE MARINE ENGINE.

A Marine Engine requires more skill in handling, in proportion as its size increases, and its mechanisms therefore multiplied.

In the Small Sizes such as are used for Launch Engines it is simply a non-condensing engine, with a link motion for varying the point of cut-off as well as for reversing purposes. Figs. 75 and 76 represent an engine of this class constructed by Chas. P. Willard & Co.

The Cylinder is what is called "inverted", meaning that it is above the crank-shaft.

The slide-spindle or valve-rod passes through a guide and connects direct to the link-block or die, as it is sometimes called.

The thrust-block is provided in the bearing of the crank-shaft and consists, as seen in the end view, of a series of collars on the crank-shaft bearing.

A larger sized engine, and a representation of the class of engine used in the smaller sizes of coasting vessels is shown in Fig. 80, which represents a Compound Condensing Marine

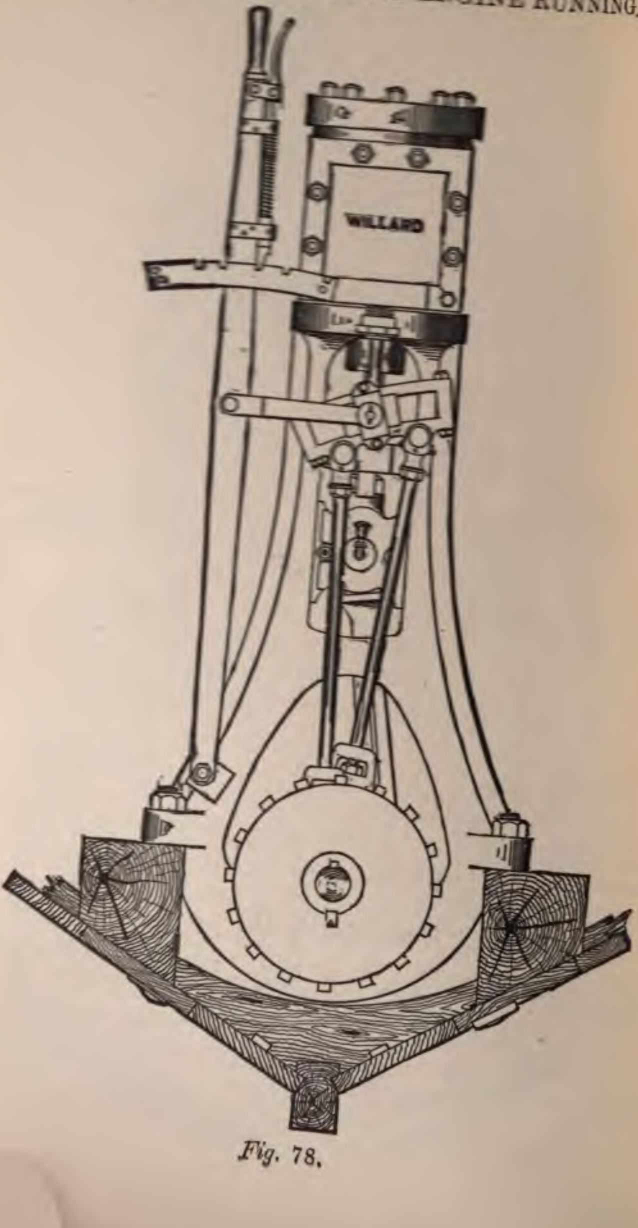


Fig. 78.

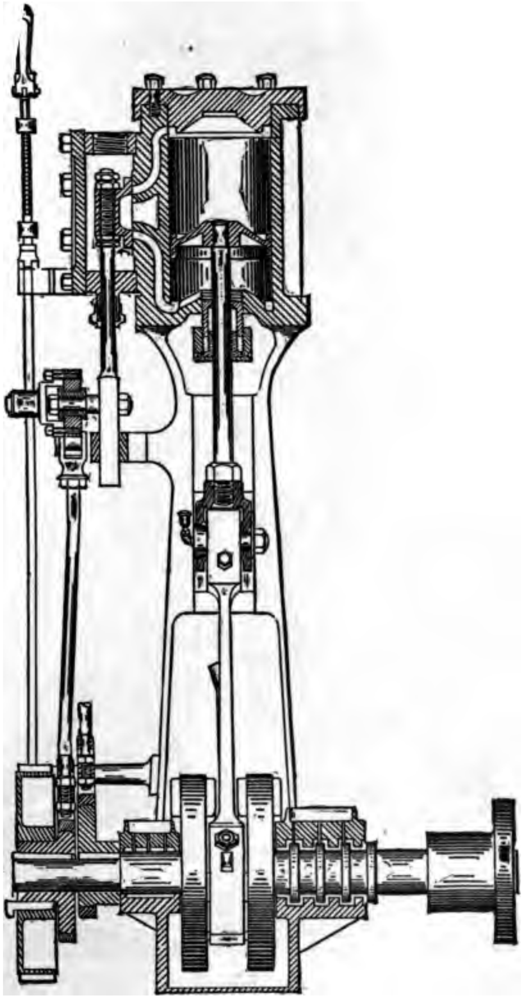


Fig. 79.

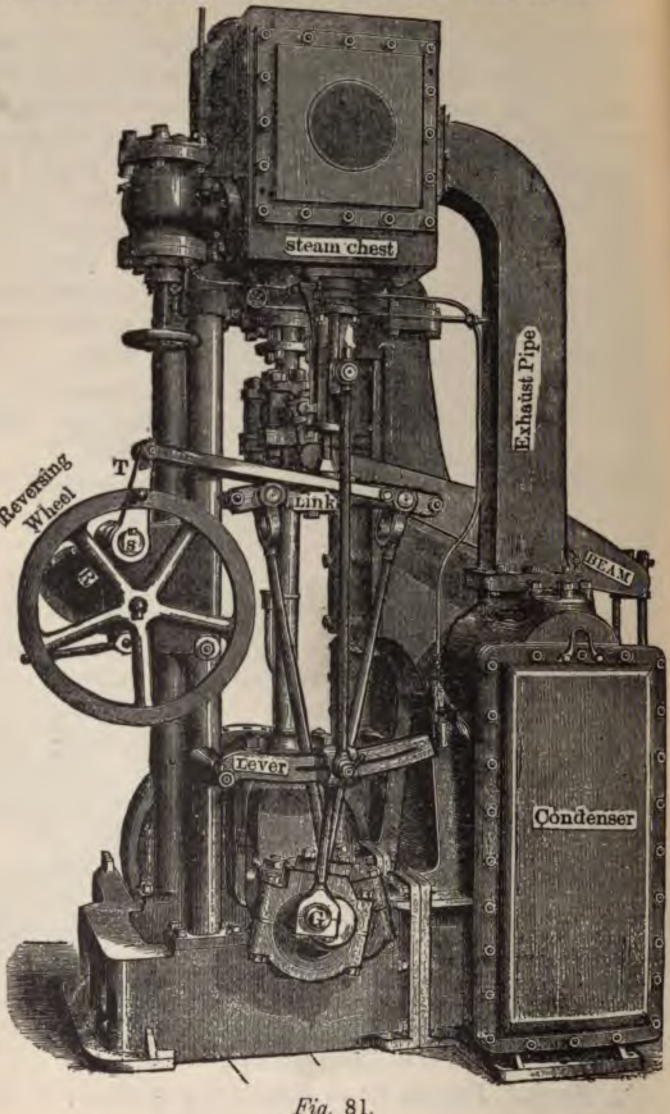

steam chest
Exhaust Pipe
T
Reversing Wheel
Link
S
R
BEAM
Lever
Condenser
G

Fig. 81.

Engine, in which the link-motions are employed to vary the points of cut-off of both cylinders, as well as to reverse the engine. The engine being small the power required to move the links is small enough to permit of their operation by hand, by means of the hand lever L, which is secured to its adjusted position on the sector T, by the small hand screw shown on the side of the lever. The lever L operates a shaft D which shifts both link-motions. The air and circulating pumps are at the back of the condenser, being operated from the beams B B′, each beam connecting to rods *r* which connect to rods *c*, which drive air and circulating pumps.

The steam from the high pressure cylinder exhausts into a receiver or chamber between the two cylinders, and from which the low pressure cylinder receives its steam.

The exhaust from the low pressure cylinder passes into the condenser where it is condensed, leaving a partial vacuum on the exhaust side of the low pressure piston.

A Marine with adjustable cut-off is shown in Fig. 81. The link-motion is here used for reversing purposes, and is, therefore, always in full gear either backwards or forwards as the case may be. The cut-off is driven from a small crank G operating an arm or lever, shown pivoted at one end, and as the point of connection on the lever is fixed, therefore it vibrates to a constant amount; the cut-off valve rod however, may be moved to connect at any required point along the lever, it being obvious that the further it is set from the pivoted end of the lever, the greater the valve travel will be, and the later the point of cut-off.

The Reversing wheel actuates a worm gearing with the segment R, which is on the same shaft as the arm T, a rod from which connects to the link.

The spindle of the cut-off valve is guided at its lower end, because the rod from the lever works at an angle.

A Marine Engine for an ocean going steamship of the

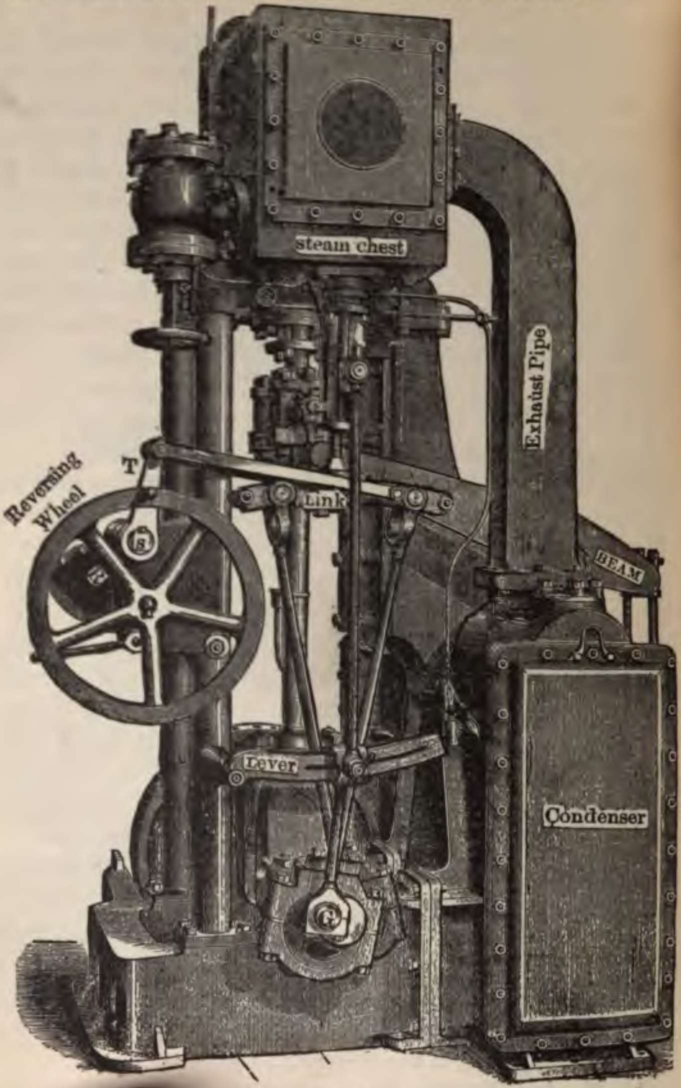

steam chest
Exhaust Pipe
Reversing Wheel
T
S
E
Link
BEAM
Lever
Condenser
G

Fig. 81.

larger sizes contains the following parts:

1st. The Power Transmitting Mechanism.

2nd. The Valve Gear which includes a cut-off mechanism or variable cut-off.

3rd. The Reversing Gear which sometimes also serves as the cut-off gear.

4th. A Condenser with air and circulating pumps.

5th. A Governor.

Marine engines are made in the following forms:

1st. With a Single or with two cylinders receiving live steam from the boilers, and these are called the high-pressure cylinders let the steam pressure be what it may.

2nd. The Addition to the above of a low pressure cylinder to each high pressure cylinder constitutes a *Compound engine.*

3rd. Triple Expansion Engines have in addition to the above an *intermediate cylinder* placed between the high and low pressure cylinders.

In a Compound Engine the low pressure cylinder receives the steam that is exhausted from the high pressure cylinder and merely expands it further.

In a Triple Expansion Engine the intermediate cylinder receives the steam that is exhausted from the high pressure cylinder, and expands it further. The low pressure cylinder receives its steam from the exhaust of the intermediate cylinder and exhausts into the condenser.

There are two Principal Methods of compounding, in one of which the two cylinders are placed one above the other with their axes in line, and both pistons connecting to the same crank, while in the other the cylinders are side by side and each connects to its own crank, the two cranks usually being at a right angle.

Triple Expansion Engines usually have their cranks 120 degrees apart so as to be equally spaced.

When in a Compound Engine one cylinder is placed above and in line with the other; both cylinders are jacketted, and the jackets are lagged to prevent cylinder condensation.*

When the Cranks are at a right angle the receiver acts as a steam jacket.

A Receiver is a chamber which is intermediate between the high and low pressure cylinders, and which acts as a reservoir of steam for the low pressure or intermediate cylinder, as the case may be.

Each Cylinder Requires a Starting Valve (which is sometimes called an auxillary valve or a bye pass valve) which is used to warm the cylinder before starting the engine, and also (when there is no vacuum in the condenser) to admit high pressure steam when the high pressure piston is on the dead center, in which case, there being no vacuum and no admission of steam to the low pressure cylinder, the engine would not have sufficient power to start.

In some Cases the high pressure cylinder has no starting valve, the reversing gear being used to admit steam to one end or the other of the high pressure piston, and the starting valve being used to admit enough live steam to the low pressure cylinder to compensate for the absence of the vacuum.

When the Vacuum in the low pressure cylinder is maintained while the engine is standing still, its starting valve obviously need not be used, except for warming purposes before starting the engine; as soon, however, as the engine has started the starting valve must be closed.

Each Cylinder is Provided with a relief valve both at the top and at the bottom to relieve the cylinder from a heavy charge of water such as may occur if the boiler primes heavily.

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*See page 37 on Steam Jackets.

Each Cylinder is also Provided with drain cocks to permit of the escape of the ordinary water of condensation in the cylinders when the engine is started, and also for use if the boiler primes.

The Low Pressure Relief Valve also prevents the accumulation of too great a pressure in the low pressure cylinder which, from its large diameter, is not strong enough to withstand high pressure.

The Oiling Apparatus for the cylinders are arranged as follows:

In Some Cases pumps, and in others automatic or self-feeding devices are used. Oil is fed to the steam pipe of the high pressure cylinder, and this lubricates both the valves and the cylinders, but in many cases it is also fed to the steam chest so as to afford more perfect lubrication to the valve.

For the low pressure cylinder the oil is fed into the receiver and usually at a point near the slide-valves.

Large Marine Cylinders are usually constructed with a separate lining, which may be replaced when worn or otherwise required.

A Surface Condenser consists of a cast iron shell or chamber forming the back of the engine frame (as in Fig. 77). At each end of this chamber is a short partition, so that the condenser is divided lengthways into what may be called three compartments, of which the middle one is the longest and contains a number of thin brass tubes about $\frac{5}{8}$ or $\frac{3}{4}$ inch in diameter, the ends of these tubes being held in the plates or tube sheets forming the partitions. The object of providing tubes of small diameter is to obtain a large area of cooling surface.

The exhaust steam from the engine generally passes into the shell or body of the condenser, filling the middle partition and surrounding the tubes.

The Condensing or Circulating water passes through the tubes, and by keeping them cool condenses the steam and forms a vacuum or partial vacuum in the condenser, which, having open communication with the low pressure cylinder, therefore gives a corresponding degree of vacuum on the exhaust side of the low pressure piston.

In some Designs, however, the steam passes through the tubes, and the circulating water fills the middle compartment of the condenser. As, however, there is no pressure to counterbalance the weight of the water it is preferable to have the water inside the tubes, so that they are subjected to a bursting pressure, in which case they may for a given strength be made thinner, because the strength of the tube to resist bursting is greater than its strength to resist collapsing, hence the circulating water usually passes through the tubes. The chamber at the ends of the condenser permits the water to distribute through all the tubes.

In some Cases the chamber at one end is divided horizontally into two compartments, so that the water is compelled to pass through one half and return through the other half of the tubes.

The Water of Condensation falls to the bottom of the condenser, from which it is removed by the air pump, which delivers it to the hot-well.

The Hot-well is situated on the side of, and extends above the pump, whose upper end it covers, thus water-sealing the top of the air pump and preventing air from passing into it through a leaky valve or bucket.

The Top of the Hot-well is provided with a *vapor pipe* which permits the air and gases to pass overboard. This pipe erges through the side of the ship above the water line, l as there is no valve between the hot-well and the sea no ssure can possibly accumulate in the hot-well.

The Boiler Feed is taken from the hot-well either by the ed pumps or by injectors, as the case may be.

In case the Boiler Feed should stop working, however. he hot-well is provided with a pipe of large diameter, and called the overboard discharge pipe, so that the water of condensation may not accumulate a pressure in the hot-well if the boiler feed ceases.

This Over-board Discharge Pipe is provided with a weighted valve (placed at the side of the ship) which is constructed after the manner of a safety-valve, relieving the hot-well of pressure if the water accumulates, and preventing the sea water from entering the hot-well

To Prevent Loss of Fresh Water the exhaust steam from the various engines and pumps (if any) about the ship passes to the condenser and is pumped into the hot-well.

In some Cases, however, a separate and independent condenser is used for the smaller engines about the ship.

An Independent Condenser is one whose air pump and circulating pump are not worked from the main engine, and can therefore be operated when the main engine is standing still.

If the Main Condenser is independent it may be started so as to form a vacuum before the main engine is started, and thus obviate the use of the starting valve on the low pressure cylinder, except to warm the cylinder before starting.

Feed Water for the Boilers when the engine is standing is obtained by a pipe from the bottom of the condenser, so that the water of condensation of steam blown through the engine cylinders, and from the exhausts from the smaller engines about the ship, may be pumped or forced direct from the bottom of the condenser to the boiler.

This Feed from the bottom of the condenser is necessary when the air pump is not working, and the water of condensation is not pumped into the hot-well.

If the Water thus obtained is not enough to keep the boilers supplied, an auxilliary or salt water feed admits extra water from the circulating water to the inside of the condenser to supply the deficiency.

This Secondary suction pipe is provided with a valve because it must be shut off before the engine is started.

All the Drain Pipes from the cylinder pass into the condenser so as to save the fresh water.

The Air Pump is usually worked by a beam, receiving motion from the cross-head of the low pressure cylinder.

The Circulating Pump is usually worked by the same beam as the air pump, or receives its motion from some other part of the main engine. In some cases, however, an independent circulating pump is employed.

It Receives its water from a pipe leading to the sea, which is provided with an injection cock or kingston valve, placed close to the side of the ship and well below the sea level. This valve is used to shut off the circulating water and prevent its flooding the ship in case of accident to the condenser or circulating pump.

The Circulating Water after passing through the condenser discharges overboard through the circulator discharge pipe.

This Pipe is also provided with a valve placed close to the ships' side, at or above the water level, so that the opening at the ships' side may be closed, and sea water prevented from entering the ship in case of breakage to the condenser, etc.

To Enable a Surface Condenser to be used as a jet condenser in case of accident to the circulating pump, a pipe leads from the injection cock of the circulating supply pump into the bottom of the exhaust pipe or column, where it enters the condenser.

This Pipe is supplied with a spray or rose nozzle, which divides up the injection water and causes it to condense the steam as it enters the condenser.

An Additional Pipe is sometimes added to the suction side of the circulating pump, for use in pumping out the bilge by means of the circulating pump in case of emergency, and also for pumping out ballast tanks when the vessel is provided with such tanks.

An Air Valve is sometimes fitted to a reciprocating double acting circulating pump. It admits air to the water during the upstroke of the pump, and closes on the down stroke. The air thus admitted acts as a cushion to soften the shock of the water.

A Snifting (or snifter-valve, as it is sometimes called), is a valve fitted to the condenser and that opens upwards to permit of the discharge of the air and gases before the engine is started. It also serves to prevent any water from leaky condenser tubes from filling the condenser and flooding the engine cylinders. It is so loaded with dead weight that it opens automatically when the water in the condenser has reached a certain height and must be placed as low down on the condenser as possible, so as to receive the weight of the full height of the water in the condenser.

Condenser tubes are made water tight in the tube plates of the condenser by wooden or sometimes paper ferrules, which fit the tube and drive into the tube plate. In other cases, however, the tube ends project through the plates and a rubber washer is placed on the end of each tube. A covering plate is then bolted over the whole of the tube ends, the holes in the covering plate being parallel for a short distance and then reduced in diameter so as to form a shoulder. The rubber rings compress and make a joint, and the shoulders prevent the condenser tubes from working out endways from expansion and contraction. The tubes are usually about $\frac{3}{64}$ inch thick.

A Blow-through valve is a valve attached to the casing or steam chest, and connecting by a pipe to condenser to blow out the air and gases that may have collected there when the engine is standing still, and that also connects to the exhaust port of the high pressure cylinder, so as to supply live steam to the low pressure cylinder in case the high pressure cylinder should get disabled.

A Bucket Air Pump is one in which there is a valve or valves in the pump piston, hence the pump is single acting, drawing on the lower side of the piston and delivering on the upper, hence the capacity of the pump per engine revolution is equal to the diameter of the bucket multiplied by the length of its stroke. The suction or foot valve is at the foot of the pump, and the delivery valve at the head.

A Piston Air Pump is double acting since it draws on each side alternately of the piston, one side delivering while the other is drawing, hence two suction and two delivery valves are required.

A Plunger Air Pump is one in which a plunger is used in place of a piston, the delivery being due to the displacement of the plunger.

An Air Pump Trunk is a hollow brass cylinder attached to or in one piece with the piston or bucket of the air pump. The rod which drives the piston passes through the trunk, and connects to a single eye at the bottom of the trunk.

A Trunk Air Pump is necessary when the pump rod is driven direct from the crank-shaft, and therefore has sufficient lateral motion to push the pump piston sideways, which would cause friction and excessive wear to the gland that keeps the trunk tight. The delivery capacity of the pump is obviously diminished to an amount equal to the displacement of that part of the plunger that passes through the gland and within the pump bore, whereas in a piston pump the delivery capacity is only diminished to an amount corresponding to the displacement of the pump piston-rod.

A Bucket pump may in some cases be worked without either a foot or a head valve, since the bucket valve will answer for both in cases when the delivery water cannot pass back into the pump on the down stroke of the bucket.

It will, however, be more efficient with the addition of either of them and most efficient with both.

A bucket pump with a foot valve and no discharge valve would, however, suffer less from a leaky gland than if it had a discharge valve and no foot valve, because the air would on the descent of the bucket, and the opening of the bucket valve pass to the suction side of the bucket and impair the vacuum.

Let the delivery valves be where they may, the foot valve will always have some water above it, and the pump bucket will dip into this water and on lifting produce a vacuum that will cause the pump to fill with water, notwithstanding that the gland may leak air on the other side of the bucket, this air will, in a single acting pump be expelled with the water, but in a double acting pump it will impair the vacuum and therefore the suction on the gland side of the piston.

Bucket Air Pumps are provided with a valve or pet-cock on the top or delivery side of the bucket and above the bucket, when the latter is at the highest point of its stroke. This valve opens on the descent of the pump admitting air to act as a cushion between the surface of the water and the delivery valve, when the water is about to meet the latter. It obviously reduces the effectiveness of the pump, and in a double acting pump is inadmissible, because of its impairing the vacuum and the suction.

This Valve also enables the engineer to know whether the air pump is working properly.

A Pet-Cock is also supplied to the feed pumps for this same purpose.

A Bilge Injection is one in which the injection water is taken from the bilge, which may be done when the ship makes more water than the bilge pumps can get rid of.

The Fittings necessary for a bilge injection, are a cock or globe valve placed on the side of the condenser, and at or near the foot of the exhaust pipe with a spray or rose inside that pipe. From the cock a pipe, usually lead, leads to the bilge, having at its end a strainer or strum, and care must be taken that this strum does not get choked and let the condenser get hot from the exhaust steam not being condensed.

The Water in the Hot-Well of a surface condenser is usually kept at a temperature of about 100° Fahrenheit. A higher temperature than 100° Fahrenheit injures the rubber valves of the air pump, while lower temperatures cool the engine cylinders too much and cause waste from cylinder condensation. Moreover it is obvious that since the boiler feed is taken from the hot-well, it is desirable to keep it as hot as the valves, and as the desired degree of vacuum, will permit.

An Air Vessel or air chamber is a vessel fitted to the delivery and sometimes also to the suction side of a pump. Its office is to maintain a steady flow of water through the pipes.

Thus, in the case of the delivery air chamber, when the pump piston is travelling at a speed above its average for the stroke, the water accumulates in the air chamber, and the air is more compressed, while when the pump is on the dead center or at the end of its stroke and the delivery valve closes the air compressed in the air chamber continues the delivery or discharge, thus maintaining a more uniform flow.

Pumps sometimes have an air or vacuum chamber on the suction side from which the air is exhausted when the pump starts, leaving a vacuum which causes a steady flow of water up the suction pipe.

Both these Chambers are more effective as the speed of the pump increases. The chamber on the delivery side is apt to lose its air which is gradually absorbed by the water which should be let out when the pump is standing still.

Feed Escape Valves or feed relief valves are fitted to the feed pumps, so that in case all the feed water cannot pass into the boiler it may pass back to the hot-well.

The Construction of a Feed Escape Valve is as follows: It is an ordinary mitre valve held to its seat by the compression of a spiral spring, whose pressure upon the valve may be regulated by an adjusting screw, whose end abuts upon a stem provided for the purpose.

In proportion as the valve is relieved of the pressure of this spring, a greater proportion of the water delivered by the feed pump will pass back into the hot-well, hence the amount of boiler feed may be regulated by the feed escape valve, which also acts as a safety-valve, preventing undue pressure in the feed pipe.

When no Feed Escape Valve is employed the delivery water from the feed pump must pass unobstructed to the boiler, or the feed pipes may burst from over pressure, and it follows that the feed check valve on the side of the boiler must not be restrained in its amount of lift, hence it must not have a lift-adjusting screw.

The Amount of the boiler feed must, in this case, be regulated from the suction side of the pump, the suction pipe being fitted with a a cock or valve whose amount of opening may be adjusted so as to regulate the amount of water drawn per pump stroke from the hot-well.

If the Feed Valve on the suction side, or the escape valve on the delivery side of the pump, as the case may be, is adjusted to permit of a proper amount of boiler feed, and yet the feed is insufficient or ceases altogether. It may occur from the following causes:

1st. From the suction valve sticking or being choked, or from the delivery valve being choked and not seating itself, thus either letting the suction water pass back into the hot-well, or the delivery water pass back into the pump,

2nd. Through leaks in the joints of the pump, or of the suction pipe.

3rd. From the water in the hot-well being too hot.

4th. Through the spring of the escape valve having become disarranged.

5th. If two or boilers are connected and one has less pressure in it than the other it may take most of the feed water, or the water of the other may empty itself into it.

Bilge Injection. The injection water for a common or jet condenser may be obtained in one of two ways, first, direct from the sea, which is that for ordinary use, and secondly from the bilge, which is resorted to to assist the bilge pump in cases of emergency.

The Necessary Fittings for a bilge injection are, a pipe leading from the condenser to the bilge with a cock at the condenser end and a strainer at the bilge end.

This pipe should be fitted with a check valve, which opens by lifting upwards so that no water can pass down it into the bilge, or otherwise if the main and bilge injections should happen to be left open together, the water from the main injection might pass down into the bilge. This check valve should be so constructed that its amount of lift can be regulated and as much as the bilge water used for injection as the circumstances may require.

In the case of surface condensers the bilge water is drawn off by the circulating pump and used to supplement the main circulating water. The pipe from the bilge in this case leads to the suction side of the circulating pump and requires a strainer at the bilge end, a cock at the circulating pump, and a check valve.

A Ships Side Air-Pump Discharge-Valve is an ordinary dead weight mitre valve that opens to let the water pass out into the sea, but seats itself and closes if the water attempts to pass inwards. It differs from a common stop valve in being weighted, and therefore self-acting. It requires to be lifted before starting the engine, as such valves are liable to stick in their seats.

The Course of the main injection water of a jet condenser is as follows: From the rose-plate or strainer, through the injection valve and pipe to the condenser, where it mingles with the exhaust steam and from which it is pumped with the products of condensation into the hot-well. From the hot-well it passes mainly overboard through the kingston valve, but that part of it used for the boiler feed passes through the suction pipe and valve into the pump, and thence through the delivery valve, pipe and check valve into the boiler.

The Course of the main circulating water of a surface condenser is through the kingston valve (on the ships side or bottom), and the circulator inlet pipe, either direct to the condenser from which it is *drawn* by the circulating pump, or else it passes through it, and is *forced* through the condenser. It circulates through the condenser twice or thrice according to the construction, and is forced overboard by the action of the circulating pump passing through a valve on the ship's side or bottom.

The Advantages of surface condensation are, 1st., that the feed water is obtained at a higher temperature than if injection water was fed to the boiler. 2nd., the feed water is purer and therefore less water requires to be blown out of the boiler in order to keep it clean, 3rd., the boiler does not scale so much, hence its heating surface is maintained more efficient, and 4th., the boiler suffers less from expansion and expansion strains when hot feed water is used.

Surface Condensers foul from the grease with which the cylinders are lubricated and from the salt in the injection water. The condenser is cleaned by the admission of soda with the exhaust steam and by washing out.

A Condensing Engine has the following cocks or valves or cocks on the skin of the ship in the engine room. The main kingston valve for the injection or circulating water, the main delivery valve from the condenser, the bilge delivery valves, and the water service cocks for keeping the main bearings of the engine cool with streams of cold water.

A Donkey Engine is a small engine used to feed the boiler and has the following connections: A steam pipe from the boiler to drive the donkey engine and exhaust pipe into the condenser, a suction pipe from the hot-well or from the sea, as the case may be, and a delivery pipe to the boiler, a suction pipe from the bilge so that the donkey pump can assist in pumping the bilge out, a suction pipe to the condenser to circulate the water when the main engines are stopped, and thus maintain the vacuum, and a suction pipe from the water ballast tanks to pump them out when necessary.

The Pipes that lead from, or go to, the sea, are: Boiler blow-off pipe, sea injection or circulator pipe, condenser discharge pipe, and, in some cases, donkey-feed suction pipe.

The Parts of an Engine that are generally made of wrought iron, are those in which strength with a mimimum of weight and size is desired, for example, the piston-rod, cross-head, connecting-rod, crank-shaft, crank, eccentric-rods, link-motion, valve-spindle pump rods, and all studs, bolts, and nuts.

The Parts Generally made of Cast Iron are those where strength and rigidity are required, and which are difficult to forge, while weight or size is of lesser importance such as the bed plate, cylinders, pistons, condensers, and pumps.

The Parts Sometimes Made of Steel are those subject to great wear, and for which strength with a minimum of size are necessary, as piston-springs, piston-rods, connecting-rods, cranks, crank-pins and valve rods.

The Parts Generally Made of Brass are those subject to abrasion or corrosion, as the connecting-rod brasses, the bearings for the crank-shaft, the pump plungers or pistons, and their rods, linings for the pump barrels or bores, the bores of the glands, the condenser tubes, and all cocks and valves.

White metal or babbit metal is sometimes used in place of, or in connection with brasses, serving as an anti abrasion surface. It is easily renewed as it is cast into its place, but will melt and run out at a temperature of about 600° Fahrenheit.

Muntz metal is used where iron or steel would suffer greatly from corrosion when in contact with salt water. It can be forged.

The difference in the composition of cast iron and steel has never been determined, the difference lies in the percentage of carbon they contain and the structure of the metal. Cast iron will not weld.

Cast Iron is brittle, of granular structure, and always breaks short, having a very low elastic limit.

Wrought Iron is tough and fibrous, will weld but will not harden, and is stronger than cast iron.

Steel is stronger than wrought iron, and will weld and harden and temper. The breaking strain of wrought iron varies from about 42000 to 60000 lbs. per square inch of section.

Steel is Tempered by first being heated red hot and suddenly cooled (usually by plunging it into cold water) which hardens it. The surface is then brightened, and on being repeated the tempering colours appear, beginning at a pale yellow, and deepening into red, brown, purple and blue, the latter gradually fading away as the metal is re-heated to a red heat. The higher the temperature to which the hardened steel is reheated the softer or lower it is tempered.

These colors merely indicate the temperature to which the piece is reheated, since they will appear on steel not hardened and upon iron.

Case Hardening is a process that converts the surface of wrought iron into steel, which is accomplished by placing them in a box filled with bone dust, animal charcoal, or leather hoofs, etc., the box is sealed with clay heated red hot for about 12 hours and the pieces are quenched in water.

The parts usually case hardened are the link-motion, and other light working parts that are of wrought iron.

The forgeable metals used in engine work are wrought iron, steel, copper, and muntz metal. The brittle or short metals, are cast iron and brass.

Welding is the joining of two pieces solidly together, wrought iron, steel, and muntz metal can be welded.

All the metals used in the construction of marine engines expand by heat, and this is allowed for in adjusting the lengths of the eccentric-rods, or of the valve spindles when setting the valve lead. In the case of two marine boilers being connected together, the steam pipe is fitted with an expansion joint, one pipe end having an enlarged bore to receive the other. The joint is made by packing, which is squeezed up by a gland, whose bore fits on the outside of the pipe which moves through the gland bore, from the expansion and contraction.

The Piston of a marine engine steam cylinder is a disc of cast iron, into which the piston rod is secured. Its body is cored out to lighten it. Around its circumference is a recess to receive the packing ring or rings, each of which is split across so that it may be expanded (to fit the bore of the cylinder), by means of the packing or of the springs. The split is closed in the center by a tongue piece let into the ring, and fastened to one end of the ring.

To hold the piston rings or ring in place a junk ring is employed, being an annular ring bolted to the piston. The piston rings are set out to fit the cylinder bore by suitable springs. The round plugs seen on the piston face merely fill the holes used to support the core in the mould and to extract it from the finished casting.

Cylinder Drain Cocks sometimes have a check valve upon them, so that while the water may pass out of the cylinder the air cannot pass in and destroy or impair the vacuum.

Cylinder Escape or Relief Valves are provided at the top and at the bottom of the cylinders, and consist of a spring loaded valve with an adjusting screw to regulate the pressure at which they shall act. They are most needed when the boiler primes heavily, and the water might knock out the cylinder heads or covers. They should be enclosed in a case with a pipe to lead the water away, thus preventing it from flying out and scalding the engineer.

A Link Motion is a valve gear by which the engine may be reversed (caused to run in either direction), or which may be used to vary the point of cut-off. The advantage of the link motion is its simplicity and durability.

A link motion for a marine engine is usually of the Steph-

[illegible] eccentric straps [illegible] the wear of the [illegible] increases the lead [illegible] the lower port [illegible] is required [illegible] the weight of the piston [illegible] links or slots [illegible] the link.

[illegible] or a slotted bar [illegible] a block or die which connects [illegible]

[illegible] is connected to a swinging arm or [illegible] arm may be moved endways so [illegible] the link beneath the valve-rod or [illegible] in which the eccentrics are set [illegible] operates the valve to go ahead, while the [illegible] go astern. Hence all that is necessary [illegible] concerned) to reverse the engine, [illegible] endwise to the requisite amount, which, [illegible] block is at, or near, the end of the [illegible]

In proportion as the link-block is (by moving the link endwise) brought nearer to the middle of the link, the valve [illegible] reduced and the point of cut-off is hastened, thus increasing the expansion.

When the link-block is in the middle of the link, the latter is in mid gear, and the valve only opens the ports to the amount of the lead, and the link action is the same whether the engine moves backwards or forwards.

The Motion of the Link is as follows: The two ends are vibrated by the eccentrics, from the central pin of the link hanger (or suspension link) as a center of motion, while at the same time this end of the link-hanger swings in an arc of which its other end is the center of motion.

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*See page for the construction of a link motion.

In Small Engines the link is sometimes used for varying the expansion as well as for reversing the direction of engine revolution.

In Large Engines it is used for reversing only, a separate expansion valve being used for varying the point of cut-off.

In small engines the link is moved endwise for forward or backward gear by a simple arrangement of hand levers. In large engines these levers are supplemented by a worm and worm gear, and in still larger engines a steam reversing gear is used for shifting the links from forward to backward gear, or vice versa.

When there is no link motion a Joy valve gear, a Marshall valve gear, or a loose eccentric may be used. A loose eccentric is one that can be moved around the shaft to reverse the engine. It may be moved around the shaft by mechanical means, or the eccentric rods may be disconnected and the valve worked by hand to cause the engine to run in the required direction, until a pin fast in the shaft meets a lug on the eccentric and drives it, there being two such lugs or shoulders spaced the requisite distance apart on the eccentric, this plan is obviously only suitable for small engines.

A Separate Expansion Valve is a valve employed to effect the cut-off and vary the expansion. It does not affect either the admission or exhaust of the steam to the cylinder.

It is used because by its means an early point of cut-off and high rate of expansion may be obtained with a fixed point of exhaust, a fixed amount of compression, and a fixed amount of lead, whereas with the link motion alone the exhaust occurs earlier in the stroke, and the compression and the lead increases as the link is moved from full-gear towards mid gear. The expansion valve should, when the engine is to be started, be set for the latest point of cut-off. The eccentric for the expansion valve is set opposite to the crank in order that its action may be the same whether the engine runs backward or forward.

The Small Cylinders on top of the steam-chests are for the purpose of guiding the upper ends of the valve-spindles and are fitted with pistons having steam beneath, the space above being in communication with the condenser. The steam pressure on the piston supports the weight of the valves and valve gear.

The Friction of a slide valve may be relieved or reduced by excluding the steam from its back, which is done by various means, such as by a ring cast on its back and working steam-tight against a plate held independently of the valve. The interior of the ring should be open to the exhaust.

The friction of a slide valve is caused by the steam pressing it to its seat, the amount of this pressure varying with the fit of the valve to its seat, and its position over the ports, or in other words, upon how much of the valve area has steam pressing on one side only.

The Travel of the eccentric rod is the distance it moves measured on a straight line. It is equal to twice the throw of the eccentric.

The throw of an eccentric is the distance between the axis of its bore, and the center or axis from which its circumference was turned in the lathe.

Double Beat Valves are composed of two discs or mitre valves, one above the other on the same stem, so that as the steam presses on the opposite faces of the two discs the valve is balanced. The objection to their use as safety-valves is that they are balanced, and would not lift unless the areas of the upper disc was made larger than that of the lower one, in which the objection would remain that the two discs do not expand equally, hence they are apt to leak. They are sometimes used instead of slide valves but are objectionable because a separate admission and exhaust valve is required at each end of the cylinder, and because at quick speeds of revolution they fall to their seats with a shock or blow, which wears out both the valve and the seat, when a high piston speed is obtained by great length of piston-stroke, and not by high rotative speed, their use is less objectionable.

There are two kinds of compound engines, in one of which the high pressure cylinder is in line with the low pressure, so that both pistons are on one rod which connects to the same crank-pin, while in the other the cylinders are side by side, as in Fig. 82, in which H. P. is the high, and L. P. the low pressure piston.

The cranks are, in this case, at a right angle, hence when the high pressure piston is at the end of the stroke the low pressure cylinder is near the middle of its stroke. The advantage of this arrangement is, that the total piston power is divided up and delivered more uniformly to the crank, which enables the crank-shaft to be made lighter for a given power and gives a more uniform motion. In Fig. 82 V is the valve for the high pressure cylinder, and V′ that for the low; *v* is the expansion valve, and P P′ the balance cylinder for the valve gear, while R R′ R″ are the cylinder escape valves or relief valves.

Expansion joints are joints which permit the parts they connect to expand and contract without straining them. They are necessary on the steam pipe connecting one boiler to another, and on the main steam pipe from the boilers to the engine. The working surfaces require to be of brass so that they will not corrode.

They require the collar on the internal pipe of the joint (on which the gland fits) to be permanently fixed by soldering or brazing, and check nuts on the studs, so that the internal pipe shall not be blown out from the steam pressure.

This pipe is also sometimes fitted with chains or stops, in case the studs should break, or the nuts or collar strip,

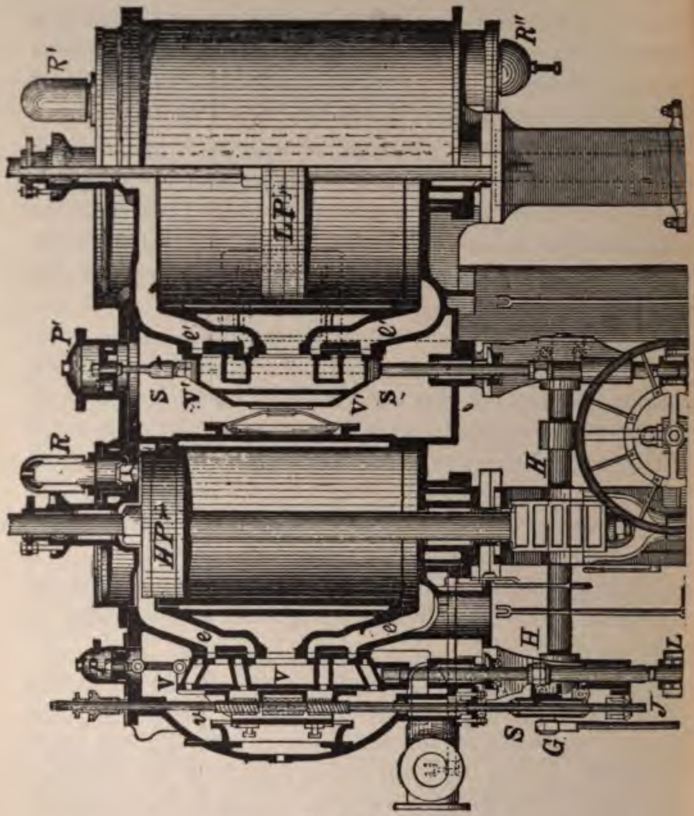

Fig. 82.

Marine Engine valve gear with Meyer cut-off valves.

An Oil Cup is either a cavity cast in the piece or a cup shaped vessel or hollow cylinder screwed in. It contains a pipe extending up about three-fourths of its height, and through this pipe the oil is fed to the surface required to be lubricated. A hinged led, or, in some casesa, screwed cap covers the oil cup to exclude dust, etc.

The Siphon or Worsted consists of a number of threads of worsted or lamp wick of equal lengths; a piece of lead or copper wire is laid across the middle of the worsted, the copper wire is doubled and twisted and is then pushed down the tube, carrying the doubled end of the worsted with it. The upper ends of the wire are bent over the end of the tube so as to hold the worsted, whose lower end should pass down below the level of the bottom of the oil cup. The oil feeds (on the siphon principle) through the medium of the wick or worsted, which should not fit the tube tight but quite easily, its upper ends hanging over the top of the tube to the bottom of the cup.

The worsted may be cleaned with scalding water, or by water thrown upon it from the boiler.

Tallow Cups for high pressure cylinders must have two cocks so that after the cup is filled the top cock may be closed and the bottom one then opened. The top cock prevents the tallow or oil from being blown out of the cock by the steam. For the low pressure cylinder a cup with a single cock will answer, as the cock may be openend when the vacuum is at that end of the cylinder and the air will force the oil or tallow in.

A Steam Lubricator or Impermeator is an automatic oil feeding device placed on the steam pipe of the high pressure cylinder. Steam lubricators are made in various forms, some having a positive feed by a pumping arrangement, while in others the oil floats upon water in the body of the lubricator to which steam is admitted; the condensation of the steam increases the quantity of water and causes the floating oil to overflow and feed through a pipe leading into the steam pipe or steam chest, as the case may be. Cooling the impermeator causes more rapid condensation, and increases the amount of oil fed to the steam.

Cylinder Escape or relief valves do not let all the water out of the cylinder because of the clearance*, hence the amount of water left in will equal the amount of clearance.

The Small Cylinders on top of the steam chest are for the purpose of guiding the upper ends of the valve spindles, and are fitted with pistons having steam beneath, the upper end being in communication with the condenser.

The effort of the piston to rise, supports the weight of the valves and valve gear.

The Valves of a Marine Engine that are worked by hand, are the stop valves for letting on steam from the boiler. The safety-valve, which is lifted to see that it is in proper working order, the kingston valve for letting in the circulating water, the blow-through or starting valve for warming the cylinders and starting the engines, the valve for adjusting the rate of boiler feed has its lift-adjusting screw operated by hand. The slide-valve may also be operated by hand before the engine is started, or it may be operated by a steam reversing gear. The expansion valves are also set by hand to regulate the point of cut-off or amount of expansion. The valves that are operated automatically, or from the motion of the parts, are the slide and expansion valves, the suction and delivery and check valves of all pumps, the air pump bucket valves, the snifting valves, and the ships side overboard discharge valves. When the engine is stopped, and the steam shut off, close the dampers to check the draught and open the drain cocks on the high pressure cylinders.

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*See page 32 on clearance.

If the engine is soon to start and the pressure in the boiler is at the blowing off point, start the boiler feed, if the height of the water in the boiler will permit it, and this is a good time to clean the fires. If the engine is to stop for any length of time shut off the impermeator and the injection supply.

A Vacuum Gauge is an instrument for measuring the total or absolute pressure, or pressure above a perfect vacuum and it is used to indicate the degree of vacuum that exists in the condenser, which, when the various joints about the cylinder and condenser are tight, averages about 27 inches of mercury when the temperature in the hot-well is about 100° Fahrenheit.

In round numbers a column of mercury 32 inches high equals the weight of the atmosphere,* hence each taking the weight of the atmosphere at sea level to be 15 lbs. per square inch, then each two inches of mercury represents an atmospheric pressure of two lbs. Suppose then that a bent U shaped tube, each leg of which is 30 inches high, is half filled with mercury, and that one end is in communication with the condenser, and the other end is open to the atmosphere, and if there was a perfect vacuum in the condenser, the pressure of the atmosphere in the open leg would force all the mercury into the leg that communicated with the condenser, hence there would be a column of 30 inches of mercury in one leg, and air in the other.

If there was in the condenser a pressure of 1½ pounds per square inch above a perfect vacuum, the mercury would stand 27 inches high in one leg, and 3 inches in the other and so on, hence from the height of the column of mercury above its natural level, the degree of vacuum in the condenser may be known. But the pressure of the atmosphere varies with its temperature, and the weight of mercury also varies with its temperature.

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*See pages 354 and 359.

To Find the Total Pressure in the condenser therefore, we subtract height of the column of mercury given by the condenser, from the height of the column in the barometer. and divide the remainder by 2.

Examples. The barometer stands at 29.5 and the vacuum gauge at 26, what is the absolute pressure in the condenser.

Here, 29.5 — 26 = 3.5 ÷ 2 = 1.75

Answer $1\frac{75}{100}$ lbs. per square inch.

A Dial Vacuum Gauge of the Bourdon construction is similar to the Bourdon steam gauge, that is used upon the boiler, except that the inside of the elliptical tube is in communication with the condenser and the atmospheric pressure bends the tube into a curve of smaller radius (instead of to a larger one, as in the case of the steam gauge).

Obviously, therefore, the zero of the dial vacuum gauge is atmospheric pressure.

Suppose the dial vacuum gauge shows 10 lbs., the steam gauge 120 lbs., and the barometer 15 lbs., and we may find the total pressure or pressure above vacuum of the steam in the boiler is as follows:

Pressure by steam gauge = 60 lbs.
A perfect vacuum = 15 lbs.

Total pressure supposing condenser had a perfect vacuum. = 75 lbs.

To make the correction necessary because there is not a perfect vacuum in the condenser, we then proceed as follows:

Barometer 30 inches. of mercury = 15 lbs. per sq. in.
Dial vacuum gauge = 10 " " " "
Actual pressure in condenser = 5 " " " "

Then:

Total pressure supposing condenser
had a perfect vacuum. = 75
Actual pressure in condenser = 5

Actual pressure of the steam = 70

Racing Means a sudden acceleration of the engine speed and occurs when the propeller is not fully immersed in the sea, as by reason of the pitching of the ship. Racing augments the strain on the working gear of the pumps, and is likely to lead to accident. It is obviated by the use of a governor or by partly shutting off the steam by hand.

A Marine Governor is a device for controlling the engine speed, by reducing the supply of steam to the engine cylinder whenever the engine begins to race. The governor is driven by band or rope, on the crank-shaft. Governors are made in various forms, thus in one the shaft has a fly-wheel and a friction clutch, one half one of which is fast on the governor shaft, while between it and the other is a spiral spring which connects the two halves. If the speed accelerates, the sliding half of the clutch is moved along the governor-shaft and by means of links it closes the throttle valve of the main steam pipe, thus wire-drawing the steam, reducing its pressure and thereby controlling the engine speed.

A Common Paddle Wheel has a cast iron center into which the wrought iron arms are set and secured by wrought iron bolts and nuts.

The bolts have hook heads to grip the back of the arm, and receive a nut and plate to secure the paddles.

Paddle wheels are sometimes provided with cast iron floats to act as counterweights to some unbalanced part of the engine, they are mostly required on side-lever engines having a single crank, they are placed nearly opposite to the crank, but not quite, so that they may prevent it from stopping on the center, and be difficult to start again.

Paddle Wheels for engines having a single crank, sometimes have their floats of varying breadths so as to keep the speed of revolution as uniform as possible. This is accomplished by making some of the floats wider than the others, the broadest floats are in action when the crank is at its points of greatest power, and the narrowest at the time the engine is on a dead center, hence there are four general graduations of breadth in the circumference of the wheel.

A Radial Paddle Wheel is one in which the floats are fixed to the paddle arms, and their ends are in a line radiating from the center of the paddle shaft.

A Feathering Paddle Float is pivoted at the center of its ends, and so arranged that by a mechanical movement it will remain vertical when in the water, notwithstanding the circular path it revolves in.

The object of feathering is to cause the thrust of the float to be as nearly as possible in a horizontal line, and therefore more nearly parallel to the line of the ships motion, and thus utilise more of the paddle power to drive the ship.

The eccentric for feathering the floats is fixed to the ships side, and sometimes carries a plummer block or pillow block for the paddle shaft bearing. The center of the eccentric sheave or wheel is placed ahead of and level with the paddle shaft axis. The working surfaces of a feathering wheel are of brass, and the bushes of the paddle arms of Lignum Vitae.

The surfaces are lubricated by the water, but sometimes oil lubrication is provided for the eccentric sheave.

A disconnecting paddle engine is one in which the paddles may be driven separately or together. This is effected at the inner port bearing by a clutch wheel, which slides endways on the shaft and is driven by feathers seated in the shaft. This clutch wheel is operated by a lever so as to engage or disengage with the crank-pin, which is fast in the outer crank.

Disconnecting paddle engines are always fitted with loose eccentrics, such engines being used for steam tugs and ferry boats, where quickness of turning, and of reversing is of great importance.

The Thread of a screw propeller is its length measured along the outer edge of the blade.

The Angle of the Thread is its angle to the axial line of the propeller shaft.

The Length of the Thread is the length of the outer or circumferential edge of the blade.

The Area is the surface of one side of the blade.

The Diameter is the distance apart of the two points on the edges that are diametrically opposite and furthest apart.

The pitch of a propeller is its degree of spirality, and is represented by the distance it would move forward if the water was a solid. It is measured by drawing a line representing the axis of the propeller shaft, and at a right angle to it, a line representing, in its length, the circumference of the circle described by the tips of the blades, from the point of intersection of these two right angle lines, a diagonal line is drawn, representing the angle the blade at its outer edge stands at the propeller shaft axis. The greatest distance between the diagonal line and the line representing the propeller circumference is the pitch of the propeller.

A Left Handed Propeller has a left hand thread or spiral, and revolves from left to right to move the ship ahead.

A Right Hand Propeller has its blades inclined in the opposite direction, and of course revolves in the opposite direction to a left hand one.

The slip of a propeller is the difference between the distance the ship is moved by the propeller, and the distance it would move if the water was solid. Slip is usually expressed in the percentage that the distance the ship actually travels bears to the distance she would have travelled if there had been no slip. From 10 to 20 percent is lost in slip.

A screw of increasing pitch is one in which the angle of the face of the propeller blade to the axis of the shaft increases as the thread recedes from the shaft, or from the center to the circumference of the blade, or in both directions.

In a uniform pitch the angle of the blade to the propeller axis is the same at all distances from the axis.

An example of a screw of uniform pitch would be a piece of angle iron wound around a parallel shaft. If wound on a tape shaft, the largest diameter being nearest to the ships stern, it would have an increasing pitch. If wound around a parabola, the pitch would vary at every point in its diameter and thread.

A Thrust Bearing is a journal-bearing provided with a number of corrugations or collars fitting with corresponding corrugations or recesses in the thrust block, the area thus provided serving to resist the end thrust placed by the propeller upon the shaft.

It must be freely lubricated by ways leading to each collar or corrugation, and so situated that it is accessible for examination. It is sometimes at the end of the first length of shaft aft of the engine.

A Stern Tube is a sleeve enveloping the aft end of the propeller shaft, to protect it from the sea water, which would corrode it. At the aft end of the stern tube is a gland and stuffing-box. At the inner end, which extends to the aft bulk head, it has a flange which is bolted to the bulk head.

The Bearing Area of the shaft and stern tube are lined with brass (about ½ inch thick), to prevent their oxidation from the action of the sea water.

A Lignum Vitæ bearing is a wooden bearing generally fitted to the outer end of the stern tube in propeller engines, or to the outer ends of the paddle shaft of paddle engines. It consists of strips of Lignum Vitæ dovetailed into the bearing or bush, and running lengthways of it, these strips are prevented from working out by a check plate at each end of the bearing.

Screw propellers may be fastened to their shafts in several ways, as by a key or feather sunk in the shaft, and projecting into a keyway in the propeller bore, and a nut on the end of the shaft with a safety-pin outside the nut, or by a key passing through the boss of the propeller, and a safety-pin or plate upon the key.

The Principal Pipes of a marine engine and boiler, and the parts they connect, are, the main steam pipe, connecting the stop valve on the superheater to the steam chest of the engine cylinders, the waste steam pipe from the safety-valve to the open air, the blow-off pipe connecting the blow-off cocks on the bottom of the boiler with the blow-off kingston cock on the ship's side; cylinder jacket pipe from the stop cock on the boiler to the steam jacket.

The Circulating suction pipe connecting the main kingston valve with the bottom of the circulating pump, the circulating delivery pipe connecting the discharge compartment of the condenser with the main delivery valve on the ships skin. The air pump suction, connecting the body of the condenser with the suction side or bottom of the air pump. The main exhaust pipe connecting the exhaust passage of the low pressure cylinder with the condenser. The feed water suction pipe connecting the donkey feed pump with the hot-well. The feed water delivery pipe connecting the donkey feed pump with the check valve on the boiler. The bilge suction pipe connecting a strum box in the bilge with the bilge pump. A suction pipe from the strum in the bilge to the donkey pump. The bilge pump delivery pipe connecting the bilge pumps with bilge delivery valves on the ships side.

A Mud Box is a rectangular box usually placed in the engine room, and serving to clear the bilge water from foreign substances, as small pieces of wood, coal, etc.; the construction is as follows: It is on the suction side of the bilge pumps and is provided with a hinged lid that affords access to clean it out, and that must obviously close air tight, or the bilge pumps will not draw. The box is divided into two compartments by a loose division plate that stands vertical, and is perforated so as to act as a strainer.

The steam from the boiler passes through the super-heater, main stop cock or valve, main steam pipe, separator, regulating and throttle valve, steam chest, steam port, steam passage into cylinder, returns through steam passage and port, exhaust cavity of valve into either the condenser or the low pressure cylinder, as the case may be, finally exhausting into condenser, whence the water of condensation is pumped by the air pump into the hot-well. In the case of a jet condenser part only of the condensed steam goes back to the boiler, the rest going into the sea through the injection discharge pipe.

A Steam Jacket* is an outer casing to a steam cylinder, the space between it and the cylinder being filled with steam direct from the boiler, with the object of preventing condensation of the steam in the engine cylinder.

A Drain Cock is supplied to the bottom of the jacket to pass off condensed water, steam jackets should be lagged or felted to prevent condensation.

The parts of an engine that require to be felted or lagged are the cylinders and the steam pipes, the boilers also should be felted or otherwise covered to prevent loss of heat by radiation, and the uptake protected by means of thin plates, kept by means of distance pieces and bolts, at a distance of two or three inches from the plates of the uptake.

Various Nonconducting Substances are employed to prevent radiation, as, for example, felt, mineral, wool, asbestos, and various kinds of cement.

The pieces of the Engine through which the steam pressure is received and transmitted are as follows:

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*See page 37 on steam jackets.

The piston, piston-rod, cross-head, cross-head gudgeon, connecting-rod, crank-pin, crank-shaft and couplings to the propeller shaft.

Trunk Engines are generally used in war vessels where it is required to have the engines below the water line. The trunk passes through the cylinder and the piston is upon the trunk, the connecting-rod passes down into the trunk and connects direct to the piston. A stuffing box and gland in each cylinder cover keeps the trunk steam tight. The trunk forms a guide to the piston in place of the ordinary cross-head and guides, and thus saves the room required by those parts.

The Cylinders for a right-handed propeller should be on the starboard side of the vessel, so that the pressure on the piston, when the engine is going ahead, shall be in a direction to lift the trunk in the cylinder, and thus act to relieve the gland and cylinder-bore of the weight of the trunk and piston.

An Oscillating Engine is one in which the cylinder is mounted on bearings called trunnions, so that the cylinder can swing and keep its bore and the piston pointing to the crank at all parts of the engine revolution. This enables the connecting-rod and slide-bars to be dispensed with. The trunnions are hollow, one containing the steam, and the other the exhaust passage.

Oscillating engines are used for paddle steamers, because their construction permits of a good length of piston-stroke, while still keeping the engine low down in the vessel.

The Valve Motion for an oscillating engine consists of an ordinary eccentric gear or motion, with the addition of various mechanical arrangements to accomodate the valve gear to the vibrating motion of the valve chest.

The Stuffing-box of an oscillating engine is made deeper than usual because the gland bore has more strain on it, and extra wearing surface is therefore required to prevent its wearing oval.

Geared Engines are those with gear wheels to increase the revolutions of the shaft above those of the engine, and thus obtain a high propeller speed without a high piston speed.

The Pressure that Propels a vessel is taken by the thrust block in a screw propeller engine.

The pressure that drives a paddle steamer is applied to the hull at the shaft bearings and their holding beams, and to the bed-plates. The amount of fuel required per horse power per hour, by modern compound engines, is from about 1½ lbs. to 3 lbs., and by common condensing engines from 3 to 5 lbs. per horse power per hour.

The Unit or Measure of a horse power is the amount of power required to lift 33000 lbs. one foot high in a minute.*

Nominal horse power is a term used to represent the commercial rating or power of an engine, and is usually based upon the area of the piston. It gives no measure of the engine power, however, because it does not take the piston speed into account.§

In a Surface Condensing Engine the duty of the air pump is to merely pump the condensed steam and vapor from the condenser to the hot-well, whereas in a jet condensing engine it has to also take the condensing water from the condenser, hence an air pump for a surface condenser may be made smaller than that for a jet condenser. As the air pump works against the pressure of the atmosphere, therefore the smaller it is, the less of the engine power is absorbed in working it.

The Injection Cocks are Regulated for opening by rods having handles attached. If the injection cocks are not open wide enough the condenser will get hot and impair the vacuum

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*See page 319.
§See page 323.

while if opened too wide, the water in the hot well will be cold and the boiler feed will be cold, these cocks should be so regulated as to keep the temperature in the hot well at about 100 degrees Fahrenheit.

The Parts of a Marine Engine that are exposed to danger in a cold climate, are all pipes through which cold water circulates, and are liable to freeze.

The Precautions necessary to prevent freezing in cold climates, are to cover all pipes liable to freeze, to keep the water circulating through them or to let it out of them if necessary, as in the case of the engine standing.

For other information concerning the engine see as follows:

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MARINE BOILERS.

Boilers for Marine Engines are, in England, made of special qualities of plate, the best being termed Yorkshire, and a nearly equal grade, Staffordshire. The plates for the shell, the furnace bottoms and the gusset stays are made of Staffordshire, while the tube plates, furnace tops, and such parts as require to be flanged and are subject to more intense heat, are made of Yorkshire plate, which has more ductility.

In the United States the grades of iron used for boilers are C H No. 1. S. or charcoal hammered No. 1 shell iron, for the shell and C H No. 1 F. or charcoal No. 1 flange iron, which is used for the furnaces and such parts as require flanging.

In Both Countries steel is also used for boilers, except for the tubes for which it is not entirely reliable if very high pressures are to be used.

Both the iron and steel plates are tested for tensile strength and ductility.

The Breaking Strain is that which is sufficient to cause rupture, while the *proof strain* is that which the metal is required to withstand with safety.

The Safe Working Strain, W P or working pressure, is the strain under which it is considered safe to work the boiler.

The Strength of a Boiler of a given diameter and thickness of plate varies according to the construction of the riveted seams or joints.

The Riveted Joints that run lengthways of the boiler are double riveted and are termed the *longitudinal* seams, they are the weakest.

[illegible] d the boiler are termed the *circumfer-* [illegible] and these are the strongest.

The Strengths of the Seams are usually stated in the percentage they bear to the solid plate of the boiler shell.

The Riveted joints are single, double, or treble riveted, and may be either chain or zigzag riveted.

In Chain Riveting the rivets in the second and third rows of rivets are in line with those in the first row, so that lines drawn longitudinally and transversely through the first row, will pass through the centers of the rivets in all the rows.

In Zigzag Riveting, each alternate row of rivets is spaced intermediate to its neighboring row.

A Lap Joint is one in which the plate edges overlap and the rivets pass through both, and are therefore in single shear, because the plates can separate if the rivet should shear or break in one place only, i. e., between the two plates to be joined.

A Butt Joint is one in which the ends to be joined, abut at their edges and a cover plate or butt strap is used.

A Cover Plate or butt strap is a band or strip of metal covering the joint, the rivets passing through the shell plate and the butt strap.

With a Single Butt Strap or cover the rivets are in single shear, whereas with a double strap the rivets are in double shear. The riveted seams bear a percentage of strength to that of the solid plate varying from about 57 to 85 per cent. according to the diameter and spacing of the rivets, the number of rows of rivets, and the method of making the rivet holes.

The Seams are made steam tight, after the riveting has been done, by caulking, which consists of setting in the edges with a caulking tool or *set* driven by hammer blows, the edge of the plate first having been planed, or in some cases chipped level.

Boiler Stays or Braces are rods, ribs, or plates for supporting the weaker parts of the boiler, thus the tube plates may be stayed by rods passing through both plates and screwed into them, or nuts and washers may be used on the stays one on each side of each tube plate.

Gusset Stays are iron plates which are riveted to **T** irons or in some cases, to **L** irons which are riveted on the surfaces to be stayed.

Stay Tubes are thick tubes (usually about $\frac{3}{16}$ inch thick), which screw into the tube sheets and are riveted over at the ends. A superior construction, however, is to provide nuts and washers to the ends of the stay tubes one on each side of each tube plate.

Boiler Stays are usually made of such diameters that when new, they will sustain a tensile strain of not more than 5,000 lbs. per square inch of cross section, this being the rule of the Board of Trade.

Stays are Sometimes Screwed into the tube plates and then riveted over at the outside ends. A better method, however, is to let the ends of the stays receive a nut on each side of each tube plate.

Boiler Tubes are Secured in their tube plates by being *expanded* in. This may be done by driving in a taper steel mandrel, and then clinching them over, or by using a tube expander. There are two principal kinds of tube expanders, in one of which small rolls travel around the bore of the tube and expand it, while in the other a number of segments, held together by a spring, are forced outwards by a mandrel driven in by hammer blows.

Too Much Expanding is apt to weaken the tube close to the inside face of the tube sheet.

Boiler Tubes Leak first at the end which receives the greatest heat from the fire, the leakage being caused by the expansion and contraction of the tube, which is obviously hotter than the water which causes the tube to expand more than the boiler shell. The remedy is to re-mandrel or expand the tube.

The Scale That Forms on the face of the tube sheet keeps the water away from contact with the plate, which with an undue thickness of scale will crack between the tube holes.

A Tube That is Split or that cannot be made steam tight by being re-mandrelled or expanded is plugged up at each end by means of either wooden or iron plugs. The best plan, however, is to use iron discs having a stepped diameter so that one end will fit the bore of the tube, and the other will form a shoulder that will cover the end of the tube.

Each disc has a hole through its center, so that a wrought iron rod or bolt may be passed through the hole, and receive a nut at each end. Beneath the flange of each disc, a grummet of spun yarn and white lead is placed, so as to make a steam tight joint when the nuts are screwed home, this stays the tube plates as well as stopping the leaky tube.

If Wooden Plugs are used, they are made a driving fit in the tube bore, and driven through until they have passed the split, and a second wooden plug is driven tightly from the same end of the tube.

The Most Rapid wasting of the plates of a marine boiler occurs alongside the fire-bars, on the furnace tops, at the back of the flame-box or combustion chamber, and in those plates generally that receive the most intense heat, and especially when they are heavily coated with scale and are not covered with water.

The Uptake of the boiler is the passage through which the heat passes after finally leaving the tubes.

A Wet Uptake is one which passes through the boiler, and therefore has fire on one side and steam on the other. It is therefore under a collapsing pressure.

A Dry Uptake is one which is outside of the boiler, and is not, therefore, under steam pressure.

The Furnace of a marine boiler extends from the fire door to the combustion chamber, (*i. e.* the box in which the heat of the furnace passes before returning through the tubes).

The Superheater of a marine boiler is a cylindrical vessel receiving the steam from the boiler, and delivering it to the main steam pipe, whence the steam is delivered to the engines, etc., when it has no connection with the uptake, it may, however, be more properly termed a steam drier, since it serves to separate the steam from entrained water, and does not superheat the steam.

In some cases, however, the superheater takes the form of a spherical ended cylinder standing in the uptake, in which case it superheats the steam.

Superheated Steam is steam to which heat has been imparted after it has left the steam space in the boiler, but the heat thus imparted is latent or not shown by the thermometer.*

Superheating evaporates entrained water, and therefore prevents or reduces the amount of priming.

The Fittings essential for a marine boiler are: The safety-valves; the test-cocks (or gauge-cocks as they are sometimes termed); the water gauge-glass; the stop-valves; the check-valve for the boiler feed pipe and the valves for letting on steam to the main engine and such other engine or engines as may take steam from the main boiler; the scum cocks; the blow-off cocks; and a small cock to enable the drawing of water from the boiler to test its degree of saltness.

There are two kinds of safety-valves, the dead-weight and the spring-loaded.

A Dead-weight safety-valve is one in which the valve is held to its seat by dead weight, the objection to which is that when the vessel rolls the effect of the weight or weights upon the valve is diminished; hence under heavy rolling the steam may blow off at a less pressure than the valve is set for.

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* See page 299 on superheated steam.

A Lock-up safety-valve is a dead-weight safety-valve, the top of whose spindle is provided with a cast iron cap or bonnet with two handles on. This cap is keyed to the spindle, and the keyway is so disposed that no extra weight can be added to the valve, while at the same time the valve can be lifted from its seat and turned around.

A Spring-loaded safety-valve is one in which the valve is held down by the pressure of a spiral spring, and this pressure will obviously not vary no matter how much the ship rolls.

In proportion as the valve lifts and the spring compresses its resistance increases, and this tends to impair the accuracy of the valve. This however is offset from the fact that when the valve rises from its seat it presents a greater area for the steam to act against.

The Area of safety-valve required by the English Board of Trade is about ½ square inch of valve area per square foot of fire-grate area.*

There are three test-cocks, which are sometimes placed in a diagonal row on the front of the boiler, and sometimes on the fitting for the gauge-glass. The top test-cock shows highest level to which the water should rise in the boiler, and the lowest one the lowest level, the middle cock indicating the average. There is usually a vertical distance of about 4 inches between the test-cocks, which gives a permissible range of 8 inches in the level of the water in the boiler.

Test-cocks are prevented from choking with scale, by passing a wire through the cock and clear into the boiler, a plug being provided, which, when removed by unscrewing, permits the insertion of the wire.

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*See page 290 for safety-valve calculations.

This cleaning must obviously be performed when there is no steam on the boiler.

A Gauge-glass is a glass tube whose bore is open to the boiler. It is fitted at each end to a brass socket that is screwed into the boiler, each socket having a cock that permits communication between the gauge-glass and the boiler to be shut off in case the glass should break. The bottom socket is also fitted with a cock, which, on being opened, permits the water and steam to blow through the gauge-glass and clean it of scum or dirt.

The Gauge-glass must be plainly in sight, and placed at such a height that when the desired quantity of water is in the boiler it will half fill the gauge-glass.

Glass water gauges instead of attaching to the boiler are sometimes fitted to a fitting that connects to the top and bottom of the boiler with the object of obtaining, for the gauge glass, water free from the scum and impurities which collect at and near the surface of the water in the boiler. This fitting should have cocks in each pipe leading to the boiler, so that in case the gauge-glass breaks, steam can be shut off from the boiler.

In some cases the test-cocks are also attached to this fitting, and in this case the construction should be such, that shutting off communication between the gauge-glass and the boiler will not at the same time shut off communication between the test-cocks and the boiler.

When the boiler is priming or steaming very fast, the gauge-glass may show a false water level, hence reading should be compared with that of the test-cocks.

If the Water Gets Too Low, the first parts of the boiler to be injured will be the top of the flame-box or combustion chamber, and the top row of tubes, because they are the first surfaces that the water will fall below and leave exposed to the heat without having water on the other side.*

The Pressure in the Boiler is shown by a steam gauge, pressure gauge, or dial gauge as it is promiscuously called.

A Bourdon Dial Gauge or pressure gauge consists of a dial casing, containing a hollow thin brass hoop, oval in cross section, which receives steam from the boiler.

This hoop is fixed at one end, while the other end is closed and free to move. The free end is connected by a small link to a toothed sector, which gears or engages with a small pinion fast upon the spindle of the pointer or needle. When the steam is admitted into the hoop it straightens out, or expands in diameter to an amount that is proportionate to the amount of the pressure within the hoop, and thus causes the needle or index pointer to revolve, and denote from the markings or readings of a dial plate, the amount of pressure within the hoop.

If the pressure within the hoop is released, it will move to its normal or zero position. In the course of time, however, the hoop is apt to get a slight permanent set, and not indicate correctly. It may, however, be approximately tested for accuracy, by testing its readings with that of the safety-valve.§

The working parts of the gauge, and its casing also, are made of brass, so that they shall not corrode, and to prevent the heat of the steam from permeating the gauge and impairing the action from expanding the parts, a small quantity of water interposes between the gauge and the steam, the construction being as follows:

Outside the gauge casing the steam pipe is bent into a loop forming an inverted siphon, which is to contain the water.

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*See page 15 on low water in boilers.

§See pages 1 and 290.

At the Lowest point in the bend of the siphon a small cock is inserted, which lets the water out of the leg of the siphon nearest to the boiler, because water in that leg would, from its weight, cause the gauge to show a pressure higher than that in the boiler.

The Pressure Shown by a steam gauge is that above atmosphere* and not that above vacuum.

The Stop Valve of a marine boiler is a valve that is opened to let the steam into the main steam pipe.

A Blow Off Cock is a cock employed to blow off, or let all, or a part of, the water out of a boiler. There are generally two, one on the bottom of the boiler, and the other at the ship's side, so that if the pipe was to break or get damaged, the cock at the vessels side can be closed to keep the sea water out, while that on the boiler may be closed to keep the water and steam in the boiler. These two ends cannot obviously be obtained if one blow off cock only was used.

Blow Off Cocks are opened and closed by a spanner or key that is removable from the cock, and to prevent the possibility of taking off the spanner or key, before the blow off cock is closed, a spanner guard is employed.

A Spanner Guard is a cap having a lug or tongue, which projects into the hole in the spanner guard, through which the spanner or key must pass before it can fit on the head of the blow off cock, and the key or spanner has a corresponding recess so that the spanner or key can only be put on or taken off when the cock is closed.

Blowing Off a Boiler is emptying it entirely as for examining the whole interior of the boiler.

Blowing Down a boiler is letting out a portion of the water so as to carry off the loose scale, mud, or sludge that y accumulate on the bottom of the boiler. The mud sludge would form into scale if allowed to remain.*

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*See page 318 for remarks on total pressure and pressure by gauge.

A Scum Cock is a cock employed to blow off a portion of e surface water in a boiler, and thus remove the scum, salt, d impurites which float or are thrown up to the surface.

Two Scum Cocks are employed, one on the side of the oiler, and one on the side of the ship. These two cocks are onnected by a pipe. That on the boiler is placed a little below the working level, which is supposed to be (and is kept as nearly as possible) about 9 inches above the top row of tubes.

Sluce valves are doors sliding, water tight, in ways at the entrance to the bulk heads on both sides of the ship. They should be worded from above in order that they may be shut, when the depth of water in the bulk heads might prevent them from being worked from below. These valves should be operated occasionally to ensure that they slide easily and are in working order.

Scale in marine boilers, using salt water, is composed of sulphate of lime, it is most objectionable on the furnace tops, on the sides and tops of the combustion chamber, on the tubes and on the tube plates. It may be prevented to some extent from forming, by a rapid circulation of the water in the boiler, by blowing down the boiler through the scum cocks, by the suspension in the boiler of zinc plates in contact with iron ones, by impregnating the water with chemical antidotes, which maintain the impurities in the form of mud or sludge, and by purifying the feed water. If surface condensers are used scaling is obviously diminished, by feeding as little salt water as possible, which may be done by not getting up a steam pressure high enough to cause the safety valve to blow off, and by preserving the water from the exhausts of the donkey or other engines about the ship.

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*See page 15 on blowing off and blowing down a boiler.

A thin coating of scale, as say $\frac{1}{32}$ inch thick, may serve as a protection against the chemical action of water that would act to corrode the surfaces, as in the cases of harbours receiving the waste water from chemical works or other impure waters. A thick coating of scale causes the plates to burn on the side receiving the furnace heat, and causes blisters to rise, while at the same time it decreases the value of the heating surface.

Scale on the tubes causes them to expand more and therefore leak in the tube sheets.

This extra expansion sometimes breaks away the scale at the neck of the tube in the tube sheet and gives access to the water there, and the chemical action of water will in some cases cause the tube to be eaten through close to the tube plate.

Scale is Removed mechanically by chisels, scrapers, and chipping hammers, which are applied to all the surfaces that can be got at from the inside of the boiler (the manhole affording access to the boiler). After the scale has thus as far as possible been removed, it is washed out of the boiler. The efficiency with which scale may be removed from the tube sheets and tubes, depends, to a great extent, upon the facilities the arrangement of the rows of tubes affords in giving access to the scaling chisels).

The Salinometer. Salt water is heavier than fresh water, hence the amount of saltiness of water may be known from its density or weight. A salinometer is an instrument that determines from the density of the water, the amount of salt contained in the water. It consists of a graduated stem at whose extremity is a weighted bulb which partially sinks the tube in the water, the depth to which the bulb sinks shows the density of the water.

The reading of a salinometer is taken at the water level, and is read on the tube which is graduated as follows: The mark furthest from the bulb or highest up the stem is marked O, and if the zero line is level with the surface of the valve in which the salinometer floats, it indicates fresh water. If salt be added to the fresh water the salinometer will rise in the water, and when the water contains 1 lb. of salt to 32 lbs. of water (which is the average degree of saltiness of sea water), the line marked $\frac{1}{32}$ on the salinometer tube will be level with the surface of the water. If the saltiness of the water be increased the salinometer will rise in the water until at 2 lbs. of salt to 32 lbs of water, a line (on the tube) marked $\frac{2}{32}$ will be level with the surface of the water. The space between the $\frac{1}{32}$ and $\frac{2}{32}$ is divided into halves and quarters.

As the density of water varies with its temperature therefore the readings on the salinometer must agree with some specific temperature, which is usually 200° Fahrenheit, and the reading of the salinometer is correct only when the water is at that temperature. If, however, the water varies a few degrees from the standard of temperature for which the salinometer is marked, a correction of the reading may be made by adding $\frac{1}{8}$ of $\frac{1}{32}$ for each 10 degrees that the water is hotter, or subtracting the same for each 10 degrees that it is cooler than the temperature at which the salinometer is correct.

The Density or specific gravity of ordinary sea water is 1.027 (that of distilled water being unity or 1.) and it contains about 4 oz. of salt per imperial gallon.

Tallow is sometimes forced into a boiler fed with salt water to stop priming, by means of a syringe that is screwed into a tallow cock provided upon the boiler below the water level. If the boiler is fed with fresh water tallow is apt to cause priming.

Angle Irons are used in boiler construction to be rivetted to plates that require supporting or strengthening, or for gusset stays to be rivetted to. Flanged plates are used in th construction of the furnaces, flame, boxes or combusti chambers, boiler ends and tube plates or tube sheets.

Division Plates are fitted in some boilers to prevent th water from passing from one side of the boiler to the other when the vessel rolls heavily. This prevents some of th tubes from being left uncovered by water and thereby getting injured from undue heat.

These Division Plates are neither steam nor water tight, and stand fore and aft of the ship. Similar division plates are sometimes used, however, to prevent the tops of the combustion boxes from getting overheated from the motion of the ship leaving them uncovered with water, their location being subserved to this end and varying with the position of the boiler.

The Superheater of a marine boiler is provided with a safety-valve, and sometimes with a pressure gauge to enable the comparing of the steam pressure with that in the boiler, and should also be provided with a gauge glass, to show when heavy priming is going on.

The Main Stop-Valve is upon the superheater, as is also the blast pipe.

Priming is a lifting, into the steam space of the boiler, of a part of the water and may arise from heavy firing, from the safety-valve blowing off, from too ltttle steam space, and from other causes.

Priming* often occurs when the boiler feed is changed from salt water to fresh water, or from fresh to salt water.

A Separator or Interceptor is a device fitted to either the superheator or to the steam receiver, for separating entrained water from the steam. It consists of a rectangular box or chamber with a partition plate extending from the top half down into the box.

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*See page 16 on priming.

The entering steam strikes the face of the partition plate against which the water collects, and from which it drops to the bottom of the box while the steam passes under the partition and out at the other side to the engine.

The Draft of a boiler is caused by the heat expanding the air and lightening it, thus causing it to ascend. It can be checked by stopping the exit of heated air up the funnel by means of a damper, by checking the flow of cold air into the furnace, by closing the dampers, by opening the furnace doors and letting cold air in the furnaces above the fires*.

A Blast Pipe is a small pipe leading from the superheater to the funnel and provided with a stop-cock.

It is used for letting a jet of steam up the funnel to promote the draft.

Flame seen at the top of the funnel is caused by the combustion of gases that would have been consumed in the furnace had there been sufficient air or sufficient room for complete combustion. It may be caused in a variety of ways, as insufficient openings between the fire bars, too narrow a space between the bridge wall and the boiler, or too deep a fire upon the bars. It is detrimental, because it obviously wastes fuel.

Dampers are used to regulate the draft in the furnace, they are fitted to the ash-pits or to the funnel, and should be fitted to both, because closing a damper in the funnel sets up a certain amount of pressure in the furnace by holding the heat, whereas dampers at the ash-pit doors and none in the funnel lets the heat out and prevents cold air from getting in to promote combustion.

When There are no Dampers the furnace doors are opened instead, to check the draft, this is, however, highly injurious to the boilers.§

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*See page 166.

§See page 166,

Black Smoke is an evidence of incomplete or imperfect combustion, and may be, to a great extent, prevented by careful firing as by feeding gradually and evenly by the admission of the proper quantity of air, or by a jet of steam admitted above the dead plates.

The Furnace Bars are ordinarily of cast iron about 1¼ inches thick at the top tapered towards the bottom, and with an air space of from ½ to ⅝ inch between them.

They require less air space for Welsh than for Newcastle coal, as the latter is the flaming or gaseous coal, and burns the fastest.

The Quantity of Coal Burned in marine boiler furnaces is about 15 lbs. per square foot of fire grate area per hour, hence the quantity burnt per day with common average engines with four furnaces three feet wide and five feet long, may be found by multiplying the area of the four furnaces (60 feet), by the number of lbs. (15) burned per foot of grate per hour, which will give the total pounds weight burned per hour, which divided by 112 lbs. will give the hundred weight burned per hour, and this multiplied by the number of hours reckoned as constituting a day, gives the fuel consumption per day, based upon 15 lbs. coal per square foot of fire grate area.

The Number of Tons of steam coal burnt per day to drive an ordinary steamer of 40 feet beam, 10 knots an hour by steam alone (or without sail), will depend upon the kind of engine used. Experience teaches us that with average vessels, the beam squared equals the consumption of coal for 40 days, in the case of an ordinary jet condenser engine, 50 days with a surface condensing engine, and 60 days with a compound engine, hence in the present example, assuming the engine to be jet condensing, we may calculate the fuel consumption per day, for a vessel 40 feet beam giving 10 knots an hour, as follows;

The beam squared gives 1600 (40 × 40 = 1600), which divided by 40 (40 days) gives 40 tons per day. For surface condensing the 1600 would be divided by 50, giving 32 tons per day, and for a compound engine the 1600 would be divided by 60, giving 26 tons, 8 cwt. per day.

It is obvious, however, that calculations of this kind, in which the ratio of expansion is not stated, are the merest approximations.

The Number of Tons of steam coal that will be burnt per day with a pair of average surface condensing engines having cylinders 40 inches in diameter, will be, under average conditions, 16 tons per day, the calculations being based upon the common assumption that the diameter of one cylinder squared and divided by 100 gives the consumption of fuel in tons per day for condensing engines not compounded, thus, 40 × 40 = 1600 ÷ 100 = 16 tons of coal burned per day.

Here again, the ratio of expansion not being specified, the calculation has no real practical value.

If at Sea and Short of Coal bear in mind that the consumption of fuel per mile run is greater for fast than for slow speeds, hence the following points should be attended to:

Reduce the Speed of the ship to, say, half the usual. Regulate the fire so as to keep up full boiler pressure without blowing off. This will allow the expansion, or cut-off valve to be set to cut-off early in the stroke, and thus save steam. If, under these conditions, the steam should sometimes blow off at the safety-valve, cover up part of the fire-grate area.

Use a thin, rather than a thick, fire, but be careful that it is not so thin as to let currents of cold air pass through.

To Relieve the Boiler in Case of Emergency. Suppose an engine breaks down at a time when the fires are heavy and going full, that the steam gauge shows blowing off pressure, but that the safety-valve is stuck, or from some cause or other is prevented from blowing off, and cannot be eased or lifted, and the following is the course to be pursued:

1st. Close the ash-pit dampers and open the smoke-box door, and fire-door. If there are no ash-pit doors close the damper in the uptake and open the fire and smoke-box doors.

2nd. Start the donkey engine to feed cold water into the boilers.

3rd. Start the steam winches, and any other small engines that take steam from the main boilers.

4th. Slacken the escape-valves and open the drain cocks of the cylinders and receivers, and steam will blow through the H. P. cylinder escape-valve and drain cock at once. The H. P. slide-valve may then be worked by hand back and forth to let steam pass into the receiver and blow through its escape-valves and drain cock.

5th. Open the scum or brine cocks and keep them open, also open all gauge or test cocks, etc., about the boiler. *

A Marine Engine may Fail to Start, or may be Prevented from Starting by the following causes:

1st. The H. P. slide-valve may be off, or away from its seat, thus admitting the steam to both sides of the piston at the same time.

2nd. The engineer may have forgotton to disengage the hand turning gear from the crank-shaft.

3rd. The propeller may be fouled with a piece of timber, or by a chain or rope (these causes sometimes occurring when the ship is in port), or there may be something wrong with the outer bearing of the propeller shaft.

4th. In the case of a propeller fitted with a banjo frame (for the purpose of raising the propeller) the propeller may be locked.

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* It is not safe to draw the fire at a time when the pressure is at a dangerous point, especially a heavy, as disturbing it may temporarily increase the combustion and condense to explosion,

5th. An obstruction, as a block of wood, in the crank-pit may prevent the crank from turning.

6th. The slide-valve nut may have slackened back, thus loosening the slide-valve.

7th. The slide-valve spindle may have broken.

8th. When an engine has no auxilliary or starting, but an *impulse* valve that merely lets a puff of steam into the receiver, this impulse valve may leak, and if the escape or relief-valve on the receiver is too much loaded it may gag the H. P. piston by giving it high pressure steam on both sides, and this may throw the valve off its seat. Similarly, if the engine has an auxilliary, or starting, valve, and it leaks, high pressure steam may be admitted to both sides of the L. P. piston, thus gagging it and causing its slide-valve to throw back and away from its seat.

9th. The cylinders may be choked with water, and the drain cocks choked up.

10th. The crank-shaft bearings may be screwed up too tightly.

11th. The air or the circulating pump may be choked with water, either the air pump overflow valve, or the circulating discharge valve, being secured down.*

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* The air pump overflow valve should never be permanently fastened down. More engines have been broken down from this than from almost any other neglectful cause, because from great leaks in the condenser tubes and engines standing for a length of time, a larger quantity of water may require to be got rid of during the first few strokes of the pump than can pass through the small air or vapor pipe, which is usually fitted from the hot-well either into the bilge or else overboard. Unless the valve in this overflow pipe is heavy enough of itself (which is very rarely the case) it should be loaded by a spring or weight, so that when the puff of the air pump causes it to lift, and the vessel is rolling, sea water may not pass into the hot-well. To avoid this some engineers erroneously fasten this valve down. An experienced engineer states that in his experience five engines have been broken down from this cause alone.

12th. From the engines being allowed to stand a long time in one position, and the glands being too tightly packed. An engine should be turned a little daily when not in use.

13th. From the piston-rings being set out too tight to the cylinder-bore.

14th. From the throttle or stop-valve being shut as from its spindle being broken.

15th. From the eccentric sheave, or wheel, having shifted on the shaft, some eccentrics having a key that is not sunk in the sheave, which is done so that the eccentric may shift rather than break if it should sieze in its strap.

16th. From the H. P. piston leaking badly, or its ring being broken, which will permit the cylinder to fill with steam and the slide-valve to unseat.

17th. If the engine has been overhauled the forward eccentric may have been connected to the wrong end of the link, thus giving an improper motion to the slide-valve.

18th. The expansion may be set to cut off too early in the stroke.

19th. From the air pump rod or from the circulating pump rod being broken, or from the valves being broken.

20th. From the cylinder casing or the receiver being cracked so as to admit steam to both sides of the piston at the same time.

A Defective Vacuum, or Loss of Vacuum, may Occur from the following causes:

1st. From the glands of the low pressure cylinder leaking.

2nd. From the pet-cock of the air pump being left open.

3rd. From the joints of the connections about the condenser, leaking. *

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* To discover a leak about a condenser pass an exposed light, as a candle, about the joints, etc., and where there is a leak the flame will be drawn in towards the condenser.

4th. From the condenser being cracked and therefore leaky.

5th. From the injection cock or valve being closed.

6th. From the condenser tubes being foul for lack of being cleaned. From the L. P. cylinder escape-valves or cylinder cocks being leaky, and therefore letting in air.

7th. From the slide-valve and piston of the L. P. cylinder leaking.

8th. From the air pump valve being leaky or broken. From the circulating pump being defective, as from having leaky valves.

9th. From the kingston injection valve not being properly opened, or from its outside orifice being choked.

10th. The bilge injection may be so connected with the air pump or condenser as to impair the vacuum when its valve is accidentally stuck, and its stop-cock is left open. *

The Principal Causes of Heating are:

1st. The bearing caps being screwed down too tight.

2nd. The bearings being left uncovered, thus allowing the brick-dust, used for cleaning the machinery, the dirt from coaling the ship, or the sand used for cleaning the decks, to get into the bearing.

3rd. The oil grooves in the brasses being worn out, or too shallow, or the brasses not being cleared at the sides.

4th. Improper fitting of the distance pieces, or fit strips, between the brasses.

5th. Bad oil, or too light an oil.

6th. If the brasses are too slack and thump or pound, the back of the brass may pean or stretch, causing the sides of the brass to close in upon and bind the crank journal or crank-pin, and this will cause heating.

NOTE. It is obvious that a defective vacuum may or may not prevent an engine from starting, according to the degree of defectiveness.

PART IX.

SOME POINTS ABOUT RUNNING VARIOUS KINDS OF ENGINES.

Engines That are Used Out of Doors, or are exposed to temperatures below the freezing point, must be left so that steam leaks may not condense in any of the parts, or pipes, and burst them.

Leaky Throttle Valves may, for example, cause water to accumulate in the steam-chest and freeze, perhaps bursting the steam-chest cover.

To Prevent This let the engine stand with the crank just past the dead center so that the steam-port will be open and open the waste-water cocks on the cylinder, and also on the steam-chest if there is any.

If the Cylinder is jacketted, all the drain cocks for the jacket should also be opened.

A Leaky Check-Valve may cause the steam to condense in the pump and freeze it up solid or burst it or the pipes. To avoid this, open the pump pet-cock.

Open All the Drain Cocks on the heater and water pipes.

If the Water is Left in the Boiler all Night, it is liable to freeze.

To Prevent This Leave a well banked fire.

In Extreme Weather remember that on exposed engines the oil, if of such quality, as sperm or lard oil may freeze and prevent feeding until the bearings get hot and melt the oil.

To Prevent This use a lighter oil, as for example a mineral oil. Or in case of freezing melt the oil in the cups with a piece of wire made red hot while getting up steam in the morning.

A Good Plan to Prevent oil from freezing and yet have a good quality of oil, is to mix two parts of lard oil with one part of kerosene.

Portable Engines should stand as nearly level as possible so that the water will stand level above the tubes and crown sheet of the fire-box.

When Feed Water is Drawn from a natural supply, as from a stream, the strainer at the end of the suction pipe should be clear of the bottom of the stream where it is liable to be choked.

When the Exhaust Steam is used to feed the boiler, do not open the valve that lets the exhaust steam into the feed-water tank until a little while after the engine has started, because the oil fed to the cylinder will otherwise pass into the feed tank and may cause priming.

In Engines Having plunger pumps for feeding the boiler, it is essential to keep the plunger properly packed as a leak there impairs or stops the pump from acting.

A Guage-Glass May be Cleaned when the engine is cold, by shutting off the cocks leading from the boiler and filling the glass with benzine, allowing it to stand two hours, the benzine must be let out at the bottom of the glass tube, and not allowed to enter the boiler.

In Starting a New Engine be careful to let the bearings be slightly loose.

At First give only enough steam to just keep the engine going, and keep the hand on the throttle-valve ready to shut off steam instantly, if occasion should require.

* * *

PART XI.

PUMPS.

Pumps are Divided into the following classes:

Lift Pumps in which the water flows freely away from the pump, which performs lifting duty only.

Force Pumps which deliver the water under pressure.

Plunger Pumps in which a "plunger" or "ram," as it is sometimes termed, is used.

Piston Pumps have a piston instead of a plunger.

A Double Acting pump is one in which water enters into and is delivered from the pump at each stroke of its piston or plunger, or in other words, one in which, while water is being drawn in on one side of the piston, it is also being forced out on the other side.

A Single Acting pump is one in which the water enters the pump barrel during one piston or plunger stroke, and is expelled from the pump during the next stroke, hence the action of the suction and of the delivery is intermittent, although the pump is in continuous action.

For Very Heavy pressures plunger pumps are generally used, the plunger being termed a *ram*.

The Advantage of the plunger or ram, is that it gives a positive displacement, whereas in a piston pump a leaky piston permits the water from the suction side to pass through the leak in the piston through the delivery side.

Piston pumps possess the Advantage that there is less difference between the contents of the pump and the displacement than is the case in plunger pumps.

The Displacement of a piston pump is found by multiplying the area of the pump bore, by the length of the piston-stroke.

The displacement of a plunger pump is less than the above, by reason of there being a certain amount of clearance or space between the circumference of the plunger, and that of the cylinder-bore.

It is Desirable to Keep the clearance space in all pumps as small as the conditions will allow, especially if the pump is liable to lose its water.

Losing the Water means the falling of the suction water back into the source of supply, which may occur when the engine has to stop temporarily, and there is a leak in the suction valves.

Rotary pumps are those in which the piston revolves, an example of the most sucessful form of rotary pump being that used in the Silsby fire engine.

The advantage possessed by a rotary pump is that it keeps the water passing through the suction in a continuous and uniform stream, as it has no valves.

It may therefore be run at a high velocity, or attached direct to the engine shaft.

If a Rotary pump Leaks the efficiency is not impaired so much as in a piston or plunger pump, all that is necessary being to run the pump at a high speed.

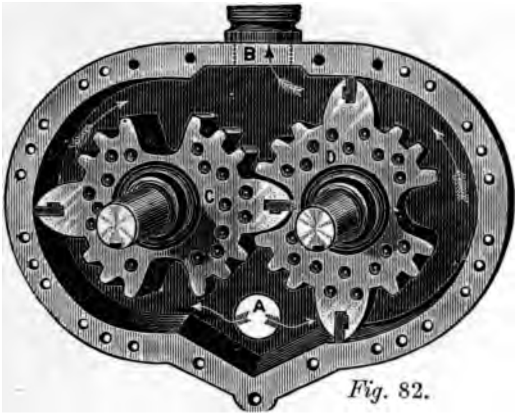


Fig. 82.

The Silsby Rotary Pump

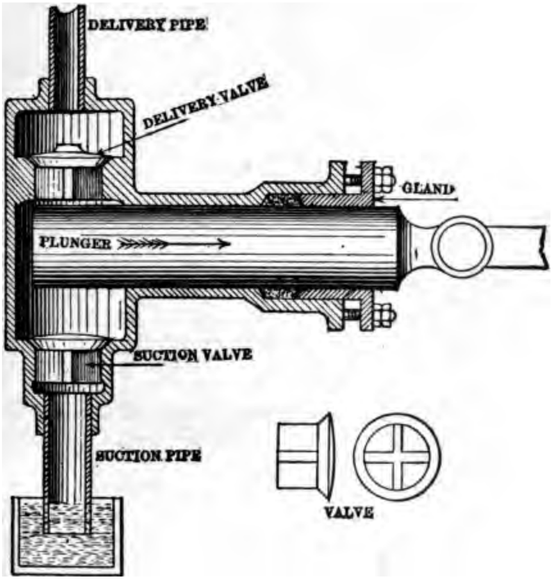


Fig. 83.

The Principles upon which a Pump acts,

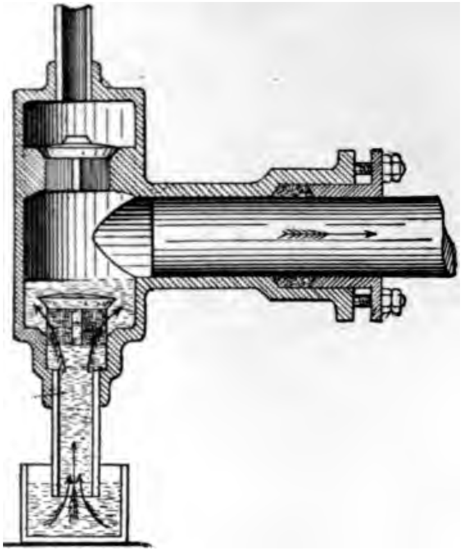


Fig. 84.

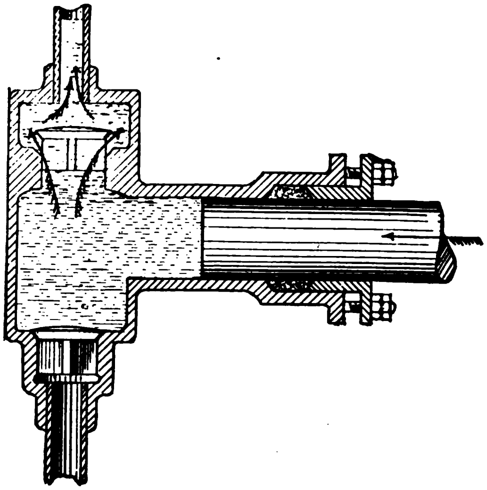


Fig. 85.

The principles of action of a pump may be understood from Fig. 83 which represents a single-acting plunger pump shown in section, and with the suction pipe in a tank of water, the pump being empty.

The Surface of the water in the tank has the pressure of the atmosphere resting upon it, and as the pump is filled with air the surface of the water within the pipe is also under atmospheric pressure.

Now Suppose the Plunger to move to the right, and as no more air can get into the pump that already within it will expand, and will therefore become lighter, hence there will be less pressure on the surface of the water within the suction pipe than there is on the outside of it. and as a result the water will rise up the pipe, not because the plunger draws it but because the air outside the pipe presses it up within the pipe.

The water inside the pipe will rise above that outside in proportion to the amount to which it is relieved of the pressure of the air, so that if the first outward stroke of the plunger reduces the pressure within the pump from 15 lbs. to 14 lbs. per square inch (15 lbs per square inch being assumed to be its normal pressure) the water will be forced up the suction pipe to a distance of about 2¼ feet, because a column of water an inch square and 2¼ feet high is equal to 1 lb. in weight. In Fig. 84 the pump plunger is shown to have moved enough to have permitted the water to rise above the suction-valve, and it will continue to rise and enter the pump barrel as long as the plunger moves to the right.

When the plunger Stops the suction-valve will fall back to its seat and enclose the water in the pump, but as soon as the plunger moves back to the left hand and enters the pump barrel further, the delivery-valve will rise, and the plunger will expel from the pump a body of air or water equal in volumn to the cubical contents of the plunger, or rather of that part of it that is within the barrel, and displaces water.

If the Plunger was at the end of its first stroke to the right and the pump half filled with air, then this air will be expelled from the pump before any water is; whereas if the pump was filled with water the latter only will be delivered.

Now suppose the first plunger stroke reduced the air pressure from 15 to 14 lbs. and that the second drawing stroke of the plunger reduces the air pressure in the pipe to 13 pounds per inch, the water will rise up it another 2¼ feet, and so on until such time as the rise of a column of water within the pipe is sufficient to be equal in weight to the pressure of the air upon the surface of the water without; hence it is only necessary to determine the height of a column of water that will weigh 15 pounds per spuare inch of area at the base of the column to ascertain how far a suction-pump will cause water to rise, and this is found by calculation or measurement to be a column nearly 34 feet high.

It is Clear Then that however high the pump may be above the level of the water, the water cannot rise more than 34 feet up the suction pipe even though all the air be excluded from it and a perfect vacuum formed because the propelling force, that is the atmospheric pressure can only raise a column of water equal in weight to itself, and it is found in practice to be an unusually good pump that will lift water thirty feet.

Fig. 85 shows the plunger making a delivery stroke, the suction valve being closed and the delivery valve open where it will remain until the plunger stops.

To Regulate the quantity of water the pump will deliver in cases where it is necessary to restrict its capacity as in the case of maintaining a constant boiler feed without pumping too much water in the boiler, the height to which the suction valves can lift must be restricted, so as to limit the amount of water that can enter the pump at each drawing stroke.

The Delivery valve should lift no more than necessary to give a free discharge without causing the valve to seat with a blow; but if the pump has a positive motion, the delivery valve must open wide enough to let the water out or pressure enough may be got up in the pump to break it.

A Check Valve is merely a second delivery valve placed close to the boiler and serving to enable the pump to be taken apart if occasion should arise, without letting the water out of the boiler.

The lift and fall of both valves acts to impair the capacity if the pump. Thus while the suction valve is falling to its seat, the water already in the pump passes back into the suction pipe, and similarly while the delivery valve is closing, the delivery water passes back.

A Foot Valve is virtually a second suction valve placed at the bottom or foot of the suction pipe.

The Capacity of a pump is from 70 to 85 per cent of the displacement of the plunger or piston, and varies with the speed at which the plunger or piston runs.

If a Pump Runs Too Fast, the water has not sufficient time to follow the piston or plunger, especially if the suction pipe has bends in it, as these bends increase the friction of the water against the bore of the pipe.

The Speed of the Piston or Plunger should not exceed such as will require the water to pass through the suction pipe at a speed not greater than 500 feet per minute, and better results will be obtained at 350 feet per minute.

An air chamber placed above the suction pipe of any pump causes a better supply of water to the pump by holding a body of water close to it, and by making the supply of water up the suction pipe more uniform and continous. Air chambers should be made as long in the neck as convenient, so that the water in passing through the pump-barrel to the delivery-pipe

Fig. 86.

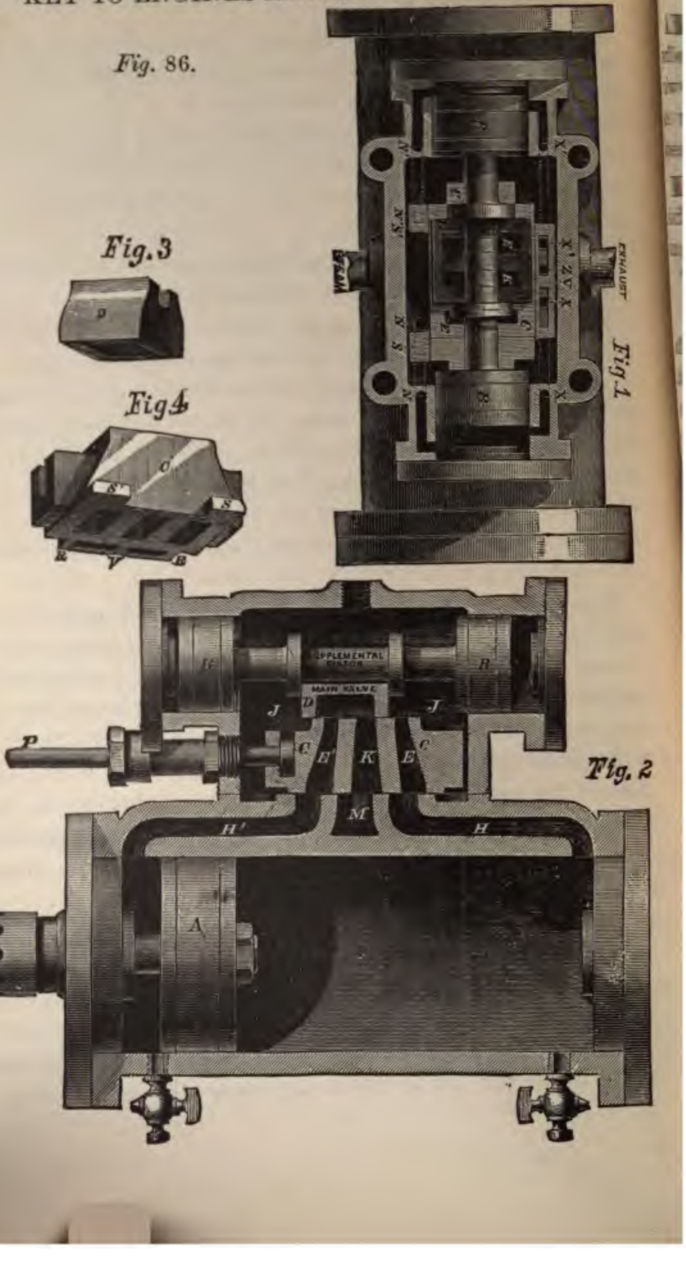


Fig. 3

Fig. 4

Fig. 1

Fig. 2

In the Blake steam pump there are two valves to the steam cylinder, one being termed the supplemental piston, B, Fig. 86, and the other the main valve, D.
The latter is seated upon a movable seat C, having steam ports E E′ and exhaust port K and being operated by the arm T striking the collars or tappets O O′, alternately the action being as follows:

When the piston arrives at or near the end of its stroke the arm T on the piston-rod, moves the collar O′ and the valve C. This merely opens the auxiliary ports N, Fig. 86, which have been covered by the lap S and S′.

These ports admit steam at once to the end of the supplemental or driving-valve piston B, which therefore moves endwise and opens the main slide valve D, which admits steam to the main piston A. The exhaust ports X and X′, for the auxiliary piston, are shown in *Fig.* 1 of Fig. 86, at R are shown the openings in the main valve, through which they free the alternate ends of the piston-valve.

The Main Piston A cannot strike the heads of its cylinder, for the main valve always has steam lead, or in other words, steam is admitted in front of the piston just before it reaches either end of its stroke, even should the supplemental piston B be tardy in its action and remain with D at that end toward which the piston A is moving, for C would be moved far enough to open the steam port leading to the main cylinder, since the possible travel of C is greater than that of D. This is a special feature, peculiar to the Blake pump.

The Supplemental Piston B, cannot strike the heads of its cylinder, for in its alternate passage beyond the exhaust ports X and X′ it cushions on the steam enclosed in the ends of its chest.

The Adjustment of this pump is confined to the position of the arm T and the collars or tappets O O′.

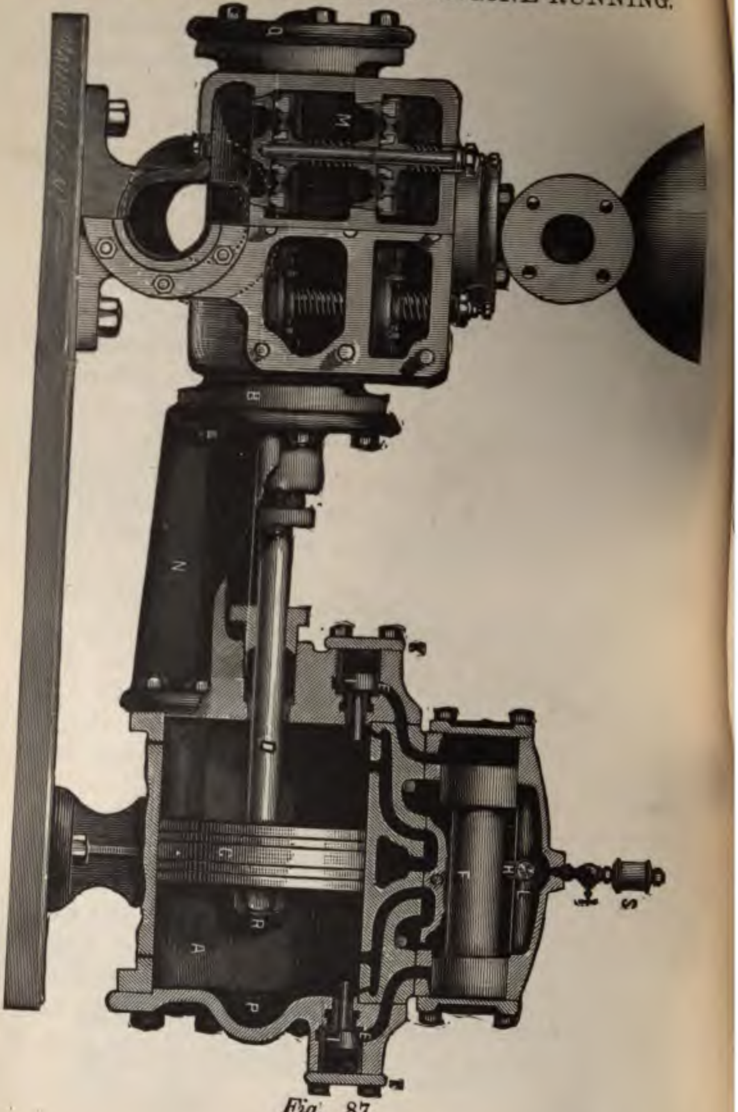


Fig. 87.

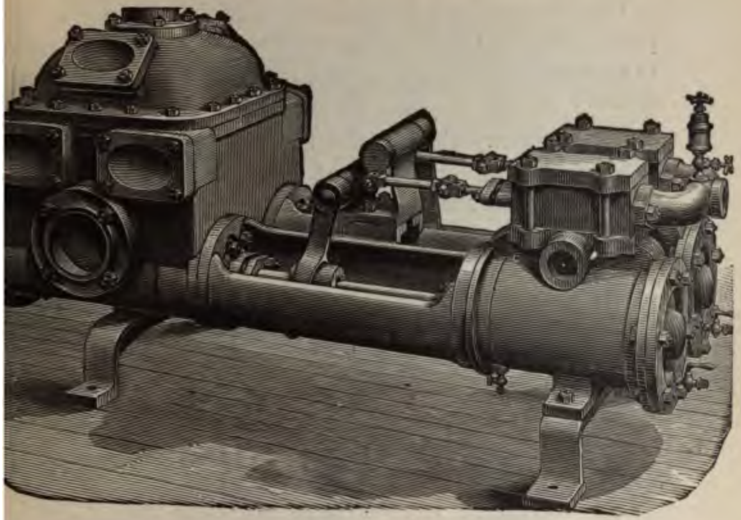


Fig. 88.

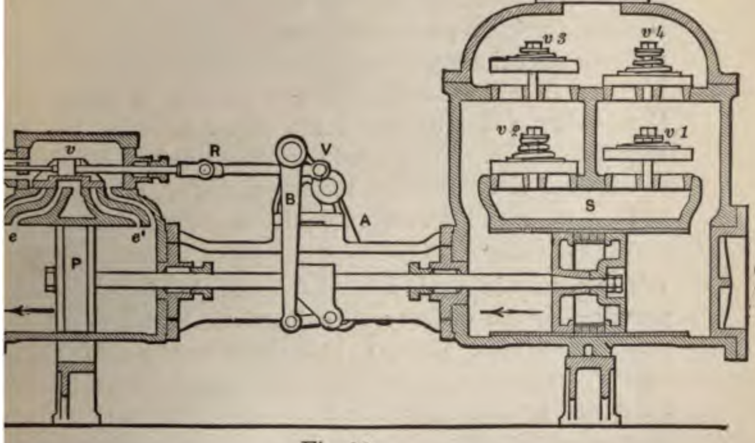


Fig. 89.

The distinguishing features are that the plunger of each pump pauses at the end of each stroke to enable the valves to seat without inducing reverse currents in either suction or delivery.

This is accomplished by the mechanism that operates the steam valve, a general view of which is shown in Fig. 88, and a sectional view in Fig. 89. The arm B receiving motion from a piston-rod actuates (through a rock-shaft V) the valve spindle R for the steam valve *v* of the other cylinder.

The end Ports are for the live steam, and the ports *e e'* are for the exhaust ports in which the steam is compressed as the piston nears the end of its stroke. The block on the valve-stem has a certain amount of lost motion in the pocket in the back of the valve which has no lap, and it is to this lost motion that the pause at the end of the piston-stroke is due.

The Adjustments of this pump are first to regulate the compression so that the piston-stroke will not be too short, means being provided for this by a valve connecting the steam and exhaust passages, so that after the piston has passed over the exhaust port and closed it the compressed steam may pass from the exhaust port into the end or steam port if necessary, and thus enable the piston to travel the full length of stroke. The second adjustment is the amount of lost motion given between the movement of the valve-rod and the valve, and the more lost motion there is the later the port opens for the live steam.

The pump is made in several forms, thus for very heavy pressures on the delivery side the plungers nearly fill the pump barrels so as to leave as little clearance as possible. For brewery purposes a piston instead of a plunger is used, while for ordinary purposes the construction is as shown in Fig. 90 the suction chamber extending along the full length of the pump cylinder, and containing a number of small valves

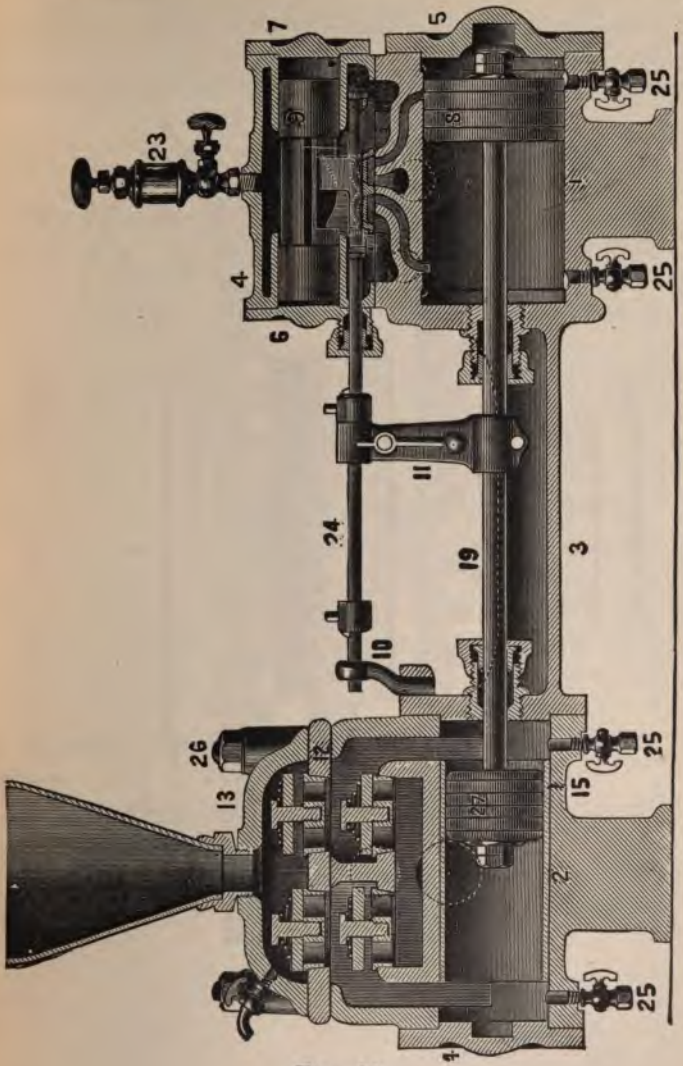


Fig. 89.

The Worthington Pump.

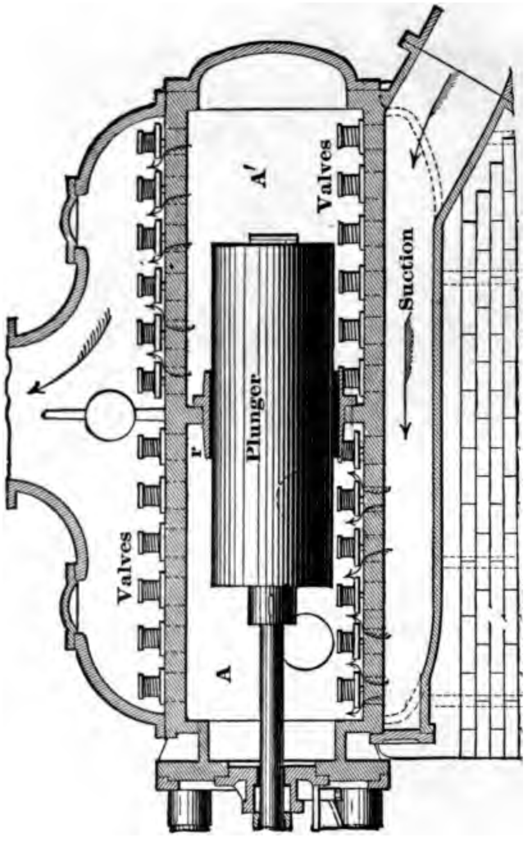


Fig. 90.

consisting of rubber disks with spiral springs at their backs. The delivery valves correspond to the suction valves, being arranged along the bottom of the delivery chamber.

INJECTORS.

The principle upon which an injector works is that the steam, on meeting the water, is condensed and the water receives the power that was contained in the steam, and the water continues to receive this power until it contains sufficient to enter the boiler.

The Over-flow of an Injector permits of a circulation to take place until the water has received enough power from the steam to be able to enter the boiler.

The flow of Water into an injector must be free and unobstructed as any impediment will stop it from working.

When the Water contains foreign matter the suction-pipe of the injector must have a strainer upon it, and this strainer should not lay at the bottom of the source of supply.

If the Injector gets Hot from any cause, as from a leak in the check-valve, it will not work, because the steam will not condense fast enough.

Injectors Usually work Best at the higher pressures of steam.

It is as Necessary to keep all the joints ot an injector tight, as it is those of a pump.

The Nozzles of an Injector must be in line or else the steam will impinge against the sides, and this will impair the action.

PART. XII.

SIMPLE CALCULATIONS FOR ENGINEERS.

"It is the first step that costs", is an adage that is very applicable to those who understake the duties of an engineer without some knowledge of calculations, hence the following information is written with a view to lay an easily acquired foundation, which will enable an engineer to make simple calculations, and with the aid of books educate himself upon the more difficult ones.

DECIMAL FRACTIONS.

By far the greater part of the calculations a beginner is likely to be called upon to make, may be made by the use of decimal fractions, which are easy to understand and to apply.

A fraction is a part of any thing, and it is clear that we may express the proportion, a part of anything bears to the whole of it in either tenths, hundredths, thousandths or millionths and thus obviate the use of vulgar fractions, such as halves, quarters, thirds, fifths, sevenths, eights or ninths.

The sign that the figure is a decimal (or that the figures

imals, as the case may be), is a dot placed before them
1 is *eleven*, while .11 is *eleven one-hundredths*, the
l sign or point being the dot.
in, 5 reads *five* while a dot before the .5 makes it
five or five tenths.
ecimal fractions the first figure on the left represents
the second hundredths and the third thousandths.
s .101 is *one tenth no hundredths and one one-thousandth*
t is the same thing, *one hundred and one thousandths.*
nany cases, however, and whenever there are more
ree decimal figures they are simply called off, ·2568
be called "*decimal two, five, six, eight*".
ecimals the addition of the figure 0, or cipher as it is
, on the right hand does not alter the value of the
n, thus ·200 *expresses, or is two tenths, no hundredths*
thonsandths.
if we add ciphers to the left hand side and move the
l point forward, we decrease the value ten times for
pher added thus ·002 is *two thousandths.*

.1 is one tenth
.2 is two tenths
.3 is three tenths
.4 is four tenths
.5 is five tenths
.9 is nine tenths
.91 is nine tenths and one, one hundredth.

ADDITION OF DECIMALS.

dding up decimals, all that is necessary is to proceed
as in simple addition, and put the decimal point
the decimal point of the figures added, thus:

1.000
.125
.018
.100
.001
1.244

We may arrange and express the figures in another way, however, thus:

$$1 + .125 + .018 + .100 + .001 = 1.244$$

The sign + means plus or added to, and the sign = means equals, is equal to, or amounts to.

The decimals alone may, however, give some whole numbers, thus:

$$\begin{array}{r} .987 \\ .862 \\ .501 \\ \hline 2.350 \\ \hline \end{array}$$

which is *two and thirty five hundredths.*

SUBTRACTION OF DECIMALS.

In subtracting decimals we proceed exactly the same as in simple subtraction, placing the decimal point in the answer beneath the decimal point in the figures above, thus:

From	.96482	From	2.00801
Take	.78901	Take	1.97641
Remainder	.17581	Remainder	.03160

We may, for convenience, state this without figuring it out in another way, thus: ·96482—.78601=17581.

The sign — means minus or less.

In placing the figures in this latter way, however, we merely state that the first sum, less the second sum, equals the third sum or answer.

MULTIPLICATION OF DECIMALS.

In the multiplication of decimals we proceed the same as in the multiplication of whole numbers, but point off in the answer as many decimal figures as there are decimals in both the multiplier and multiplicand.

$$\begin{array}{rl} .918 & \text{multiplicand} \\ \underline{.981} & \text{multiplier} \\ 918 & \\ 7344 & \\ \underline{8262} & \\ .900558 & \text{sum or answer} \end{array}$$

Here there are three decimal figures in the multiplicand and three in the multiplier or six in all, hence we place the decimal point before the sixth figure in the sum or answer.

The presence of whole numbers and decimals makes no difference, thus:

$$\begin{array}{rl} .9\,8\,7 & \text{multiplicand} \\ \underline{2.5} & \text{muitiplier} \\ 4\,9\,3\,5 & \\ \underline{1\,9\,7\,4} & \\ 2.4\,6\,7\,5 & \text{sum} \end{array}$$

or

$$\begin{array}{rl} .0\,0\,0\,1 & \text{multiplicand.} \\ \underline{2\,0\,1} & \text{multiplier.} \\ 0\,0\,0\,1 & \\ \underline{0\,0\,0\,2} & \\ 0\,0.0\,2\,0\,1 & \text{sum.} \end{array}$$

In the last case, the two ciphers on the left may obviously be omitted, as they are in the place of whole numbers, represent nothing, as the answer reads *two huudredths* and *one ten thousandth* or decimal *naught, two, naught, one* (.0201).

We may state this in another way, thus:

$.0001 \times 201 = .0201$

The sign × meaning multiplied by, and the sign = equals, comes to, or becomes.

There must always be as many decimal figures in the sum or answer, as there are in the multiplier and multiplicand added together.

Example. Multiply .002 by .006

$$\begin{array}{r}\left.\begin{array}{r}.002\text{ three decimals}\\ \underline{.006\text{ three decimals}}\end{array}\right\}\text{ six decimals}\\ \underline{.000012}\text{ six decimals}\end{array}$$

Examples for practice. Multiply .812 × .25
" 2.010 × .018
" .001 × .014

DIVISION OF DECIMALS.

In division of decimals we proceed as in common or simple division, but the pointing off of the decimal point in the answer or quotient requires attention.

Example. Divide .7218 by .6

$$\begin{array}{ll}\text{divisor} & \text{dividend}\\ .6) & \underline{.7218}\\ & \underline{.1203}\text{ quotient or answer.}\end{array}$$

We may state this in another way, thus: .7218÷.6=.1203.

The sign ÷ means divided by, and the sign = means equals, as in the previous examples.

When there are as many figures in the divisor as there are in the dividend, the quotient will contain whole numbers, unless additional ciphers are added to the dividend.

Example. Divide 74.448 by 12.448

$$\begin{array}{ll}\text{divisor} & \text{dividend}\\ 12.408) & 74.448\ (6\text{ quotient or answer.}\\ & \underline{74448}\\ & \underline{\cdot\cdot\cdot\cdot\cdot}\text{ no remainder.}\end{array}$$

In the above example the division goes just six times into the dividend without leaving a remainder, and as there are as many decimals in the dividend as there are in the divisor, the 6 is a whole number, but when there are more decimal figures in the divisor than in the dividend, we must add ciphers so as to make them equal in number and the quotient will be all in whole numbers unless there is a remainder.

Example. Divide 43 by 5.375

divisor
5.375) $43.\overbrace{000}^{\text{added}}$ (8 quotient.
43 000
· · · · · no remainder.

We have here added three ciphers to the dividend because there are three decimals in the divisor, and as there is no remainder the answer is 8 in whole numbers.

If there are more decimals in the dividend than there are in the divisor, we must add enough ciphers to the left hand of the divisor to make it contain as many decimal figures as the dividend does.

Example. Divide 123.365 by 22.43.

added ☟ dividend.
divisor. 2 2.4 3 0) 1 2 3.3 6 5 (5.5 quotient or answer.
1 1 2 1 5 0
remainder. 1 1 2 1 5 0 ☜ this cipher added.
1 1 2 1 5 0
· · · · · · no remainder.

As there were three decimal figures in the dividend, we added a cipher to the divisor giving it three also and we found it went five times, and the first figure (5) in the answer is a whole number. To the remainder, (11215) we added another cipher and this makes the next figure (the second **5**) a decimal, hence the answer is 5.5 or *five and five tenths.*

If there had been a second remainder, a cipher would require to be adedd to it, giving two decimals or “two places of decimals“ as it is termed, in the answer. We may continue adding ciphers to the remainder as long as there is a remainder, but it is accurate enough for ordinary calculation, to carry the quotient or answer to three places of decimals.

In some cases there will always be a remainder, and we may get a certain run of figures in the quotient. These are called *reciprocating decimals,* because they reciprocate or come back again.

```
.18).39(2.166
     36
     --
      30
      18
      --
      120
      108
      ---
       120
       108
       ---
        12 remainder.
```

Here we may keep on adding ciphers to the remainder, thus getting the answer more correct, and if we desire to do this, we have sinply to add as many figures 6 to the answer as we like, but as before stated three places of decimals is usually accurate enough.

We may state the result without carrying out the process of figuring. Thus: $.39 \div .18 = 2.166+$ which stated in language reads *thirty nine divided by* .18 *equals two, and one hundred and sixty six thousandths* and a remainder, the sign + meaning plus or that there is something over.

Another method of stating the result without giving the figuring by which it is arrived at, is as follows:

$$\frac{.39}{.18} = 2.166+$$

By placing the .39 over the .18 and putting a line between, it is understood that the .39 is divided by the .18

In some cases the results will be more accurate if, in the case of a reciprocating decimal, we put the next higher decimal.

For example, suppose the figures were 2.99 *plus*, and the first figure after the plus or remainder is greater than 5, then it would be more accurate, if only 3 places of decimals are used, to discard the decimals altogether and say 3, or if the figures were 2.979+ it would give results more nearly correct to use the figures 2.98 putting a minus sign — after the 8 (thus 2.98—) to show that the 8 is too much, but the nearest that can be got.

The signs we have given may be employed to advantage when it is desired to state a result, and how it is obtained without carrying out the process of obtaining it. Thus:

$$\frac{.18}{.9} \times 4 \div 3 = 266+$$

This is a short way of stating the result, which we may work out as below:

```
.9).18(2
    18 4
     3)8.00
        2.66
```

The most difficult questions or sums in decimals are, to beginners, those in which the places of tenths, hundredths and thousandths are occupied by ciphers.

Example. Multiply .003 by .002

```
   .003
   .002
.000006
```

Here we multiply 3 by 2 and get the 6 and then add to the left of the 6 as many ciphers as will make the sum or answer contain as many decimal ciphers as will make it contain as many decimals figures as the multiplicand and multiplier both put together, thus there are three decimals (.003) in the multiplicand and three in the multiplier (.002), or six in all, and there must therefore be six decimal figures in the sum or answer, hence we add five ciphers to the left of the figure and place the decimal point to the left.

A similiar example in division is as follows:

Example. Divide .003 by .000006 .

First put down the dividend, adding three ciphers to it so as to make it contain as many decimals as the divisor does. Thus:

```
.000006).003000(500
             30
            ----
             ..
            ----
```

We then disregard the ciphers to the left of the 6, and those on the left of the 3, and divide the remaining figures, finding that the quotient is 500, which is a whole number, because there are an equal number of decimals in the divisor and dividend.

We may prove the process by multiplying the .000006 by 500

```
.0 0 0 0 0 6
         5 0 0
--------------
0 0.0 0 3 0 0 0
```

A second example is as follows:

Divide .05 by .00007 .

In this case the last three figures in the quotient or answer are decimals, because we obtained them by adding ciphers after all those in the dividend had been used.

.00007).05000(714.285
49
10
7
30
28
20
14
60
56
40
35
5

REDUCING FRACTIONS TO DECIMALS.

To reduce a fraction to decimals or find its decimal equivalent, as it is sometimes termed, we proceed as follows:

Rule. Divide the numerator of the fraction by the denominator.

Examples. Reduce $\frac{1}{4}$ to decimals.

Numerator 1

Denominator 4 **Then** 4).100
.25

After we have put down the 4 as a divisor and the 1 as a dividend and find that the 4 will not go into the 1, we add a cipher, which makes the quotient decimals.

Reduce $\frac{3}{4}$ to decimals.

4)300
.75

Reduce $\frac{7}{8}$ to decimals.

8)7000
.875

Reduce ⅓ to decimals.

```
3)1000
  .333
  ----
   ...
```

In this last example we have carried the quotient or answer out to three places of decimals, but we might if great accuracy is necessary add as many threes as we like.

What is the decimal equivalent of $\frac{146}{292}$

```
divisor.  dividend.
      292) 146.0 (.5 decimal equivalent.
           146 0
           -----
            ...
```

What is the decimal equivalent of $\frac{1}{32}$

```
32) 1.00 (.03125
      96
     ---
      40
      32
     ---
       80
       64
      ---
       160
       160
      ----
       ...
```

In this example we first put down the 32 as divisor and the one as a dividend, and as it will not go, we add a cipher and begin the decimals, but 32 will not go into 10, hence we place a .0 in the quotient and add another cipher to the dividend, and the divisor will then go three times. If it would not have gone this second time, we would have to add another cipher to the quotient and then another cipher to the dividend, and try again as in the following example:

What is the decimal equivalent of $\frac{1}{1216}$.

```
1216) 10000 (.0008214
       9728
      ------
        2720
        2532
       ------
         1880
         1216
        ------
          5640
          4864
         ------
           776
```

CONVERTING DECIMAL FRACTIONS INTO VULGAR FRACTIONS.

In mechanical calculations we usually want the fraction in halves, quarters, eights, or sixteenths, because these are the subdivisions of inches and lbs., but we may convert the decimals into fractions of any required denomination by multiplying them by the denomination we want the answer in.

Example. Convert .75 into quarters or fourths.

```
         multiplicand.
              .75
               4
             ----
answer =     3.00
```

In this example we have multiplied the decimals by four, because we want the answer in fourths, and after pointing off as many decimals in the answer as there are in the multiplicand, there is a three left, hence the number of quarters in .75 is 3 or .75 = $\frac{3}{4}$.

Express .234375 in eighths, sixteenths, and other of the usual divisions of an inch.

	.234375	
	8	[there are 8 eighths in an inch.]
one eighth	1.875000	
	2	[there are 2 sixteenths in an eighth.]
one sixteenth	1.750000	
	2	[there are 2 thirty-seconds in a sixteenth.]
one thirty-second	1.500000	
	2	[there are 2 sixty-fourths in a thirty-second.]
one sixty-fourth	1.000000	

Answer $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$ or $\frac{15}{64}$.

PROPORTION OF DECIMALS.

By *proportion* of decimals we may solve a great many questions that are liable to arise in the engine room.

Suppose, for example, that we have a tank of water for boiler feeding and that we find the water drawn from it causes its level to lower 8 $\frac{3}{8}$ inches in 12 hours, and that at a certain time there remains in it a depth of 40$\frac{5}{8}$ inches, then to find out how long the water will last, we proceed as follows:

Question. If 8$\frac{3}{8}$ inches of water lasts 12 hours, how long will 41$\frac{5}{8}$ inches of water last?

Here we have three quantities given to us, two of which are inches, and others hours, and we put three quantities in a row, with the odd one in the middle as below.

Inches.	Hours.	Inches.
8$\frac{3}{8}$	12	41$\frac{5}{8}$

Now we have got to first multiply the 12 hours by one of these numbers of inches, and then divide by the other number of inches, and to decide which to multiply by, we consider whether the answer is to be greater or less, or what is the same thing, more or less.

In this case it will be more or greater, because it will take a greater length of time, or more time to empty the tank than 12 hours, so we multiply the 41⅝ by 12 and divide by the 8⅜ hours, and the quotient will be the answer.

But before we do this we must convert the ⅝ and the ⅜ into decimals and having done this the question will appear as follows:

inches.	hours.	inches.
8.375	12	41.625

```
                        41.625
                            12
                  ------------
            8.375)499.500(59.629
                  41875
                  -----
                   80550
                   75375
                   -----
                    53750
                    51250
                    -----
                     25000
                     16750
                     -----
                      82500
                      75375
                      -----
                       7125
```

The answer is 59.629 hours.

To find how many minutes the .628 are equal to we multiply them by 60, because there are 60 minutes in an hour, thus:

```
                    .629
                      60 [there are 60 minutes in an hour.
                  ------
three minutes     3.7740
                      60 [there are 60 seconds in a minute.
                  ------
forty-six seconds 46.6400
```

[illegible] steel [illegible]

[illegible] and [illegible]

[illegible] are [illegible] which [illegible]

[illegible] and then [illegible]

[illegible] the [illegible] will [illegible] by the [illegible] quantity.

10.067

[illegible] 10.0[illegible]

The usual method of stating the above question would be as below:

first term.	second term	third term
18.875	22.6875	8.375

This means that the proportion 188.75 bears to 22.6875 as that which 8375 bears to the answer. But in stating the question in this way we are to consider which is to be the first term; because we always multiply by the third term and divide by the first term.

If the answer is to be less, the smaller number or figure occupies the first place in the proportion, the other number or figure of the same denomination of the first quantity occupying the third place in the proportion, and the odd quantity always occupies the second; but if the answer requires to be more, then the largest number takes the first place in the proportion, and the lesser number the third.

SQUARE ROOT.

If we multiply a number by itself, we what is called square it, thus $4 \times 4 = 16$, or 4 squared gives I6, and if we extract the square root, we bring the 16 back to the 4 again.

The first power of a figure or number is itself, thus the first power of 4 is 4. The second power of a number is the sum obtained by doubling it, thus the second power of 4 is 8.

The third power of a number is the sum obtained by multiplying it by itself three times, thus the third power of 4 is 64. Thus:

$$4 \times 4 \times 4 = 64$$

or to carry out the process.

$$\begin{array}{rl}
4 & \text{first power.}\\
\underline{4} & \\
16 & \text{second power.}\\
\underline{4} & \\
64 & \text{third power.}\\
\underline{4} & \\
\underline{256} &
\end{array}$$

The sign that a number is squared, is a ^{2} placed on its right, thus 4^2 means 4 multiplied by itself or squared, the ^{2} representing the second power.

In square root we are simply given the second power of a number and required to find what that number is. Suppose, for example, we know that the area of the end of a bar is 16 square inches, and we wish to find the size of the bar, then by extracting or finding the square root we get 4 and 4 inches square would be the size of the bar.

Example in square root.

What is the square root of 186624?

$$\begin{array}{lrl}
 & & 18\dot{6}6\dot{2}4(432 \quad \text{quotient.}\\
 & & \underline{16}\\
\text{first divisor,} & 83) & 266\\
 & & \underline{249}\\
\text{second divisor,} & 862) & 1724\\
 & & \underline{1724}\\
 & & \cdot\cdot\cdot\cdot
\end{array}$$

Beginning at the right hand figure (the 4) of the given number we mark, along every second figure to the left, a dot, as seen over the 2 and the 6. The last figures to the left of a dot are, in this case, 18, and we must find what is the highest number that, multiplied by itself, will give either 18 or less than 18. This we know to be 4, hence we put a 4 in the quotient, and its square (16) under the 18, and by subtraction get 2 remainder. Then we bring down the next two figures 66 and place them beside the 2, getting 266.

We have now to get a divisor for this 266, and this we do by multiplying the 4 in the quotient by 2 which gives 8, and this 8 we place as the first figure in the divisor. This 8 we divide into the 266, as follows: 8 into 26 goes 3 times. And this 3 we place after the 4 in the quotient, and also after the 8 in the divisor. The number now stands thus:

$$\begin{array}{r l}
 & 18\dot{6}6\dot{2}4\ (43 \\
 & \underline{16} \\
83) & 266
\end{array}$$

We next multiply the divisor 83 by the three in the quotient, and get 249 which we place under the 266 and subtract getting a remainder of 17. Next bring down the 24 from the dividend and we have 1724, the sum standing thus:

$$\begin{array}{r l}
 & 18\dot{6}6\dot{2}4(43 \\
 & \underline{16} \\
83) & 266 \\
 & \underline{249} \\
 & 1724
\end{array}$$

To get the second divisor (for the 1724) we first multiply the 43 by 2 and get 86, which are the first two figures in the divisor, and placing the 2 we multiplied by in the quotient making it 432.

To get the third figure of the second divisor we divide its first figure (8) into the 17, and as it goes twice we put the 2 into the second divisor and multiply this divisor by the 2 in the quotient, and as $862 \times 2 = 1724$ the sum is complete, the answer being 432.

In this example there was no remainder, but if there had been one we could carry the solution further by adding two ciphers and proceed as before.

Example. Find the square root of 189797

```
        .   .
      186297(432.2 quotient.
      16
  83 | 267
     | 249
 862  | 1897
      | 1724
8642   | 17300 [these two ciphers added,]
       | 17284
          ...16
```

Answer, 432.2

We may now point out that in getting the first divisor it is sometimes necessary to take, for the first figure of the divisor, a lesser figure than would at first appear proper.

Example. What is the square root of 702.

```
      .
     702(27
     4
 47) 302
     329
```

Here we find that the 7 in the divisor is too high a figure because when multiplied by the 7 in the quotient it gives 329 which is more than 302, hence, instead of using the 7 we must use a 6, and proceed as follows:

```
                       .
                       702(26.5
                       4
                   46) 302
                       276
second divisor,  525)  2600
                       2625
```

Here we have come to the same thing again for although the right hand figure of the second divisor will go 5 times into the first two figures (26 of the dividend) yet when we come to multiply the second divisor by the 5 in the quotient we get 2625 which is more than 2600, hence we must take 4 which is the next lowest figure to 5, and proceed as follows:

```
          .
        702(26.495
        4
     46)302
        276
    524) 2600
         2096
  5289) 50400
        47601
 52985) 279900
        274925
          4985
```

The answer is therefore 26.495

We may now take an example in which there are decimals in the given number.

Example. What is the square root of 814.5625?

When there are decimals, as in this case, we point off every second one of the whole numbers beginning at the right hand, as in previous examples, but in the case of the decimals we begin at the left hand and put the point above every second figure, thus:

```
                          .   . .
                         715.5625 (26.75
                         4
    first divisor  46 ) 315
                        276
  second devisor  527 ) 3056
                         3789
   third devisor 5345 ) 26725
                         26725
                         .....            Answer 26.75
```

CUBE ROOT.

In cube root we are given a certain number that is the third power of some other number, and we are required to find out what that number is, the process being as follows:

Example. Find the cube root of 54.872

$$\begin{array}{l} 54\dot{8}72\,(\,3 \\ \underline{27} \\ 27872 \end{array}$$

We first mark a dot above every third figure beginning on the right hand, there being in this example one dot or point over the 8.

The figures to the left of the point are 54, and we have to find what number cubed (or in the third power) comes nearest to this 54 without being more than 54.

If we try 4 we find that its third power is 64, thus $4 \times 4 \times 4 = 64$, which is too much, so we try 3 and find its cube or third power is 27, hence we place the three in the quotient and the cube of 3, which is 27, under the 54 and subtract, which leaves 27.

We then bring down the next three figures and we have 27872. The next step is to multiply the first figure in the quotient, the 3 in this case, by 3 and thus get 9, which we place well out to the left of the 27872, the sum now standing thus:

$$\begin{array}{ll} & 54872\,(\,3 \\ & \underline{27} \\ 9 & 27872 \end{array}$$

Next multiply this 9 by the figure in the quotient (3) and place the result to the right of the 9, thus:

```
           548̇72 ( 3
           27
      9 27  27872
```

The figures 9, 27 and 27872 all being on a line, then put two phers after the 27 making the figures stand thus:

```
             548̇72 ( 3
             27
      9 2700   27984
```

This 2700 is called the *trial* divisor, and we want to find how many times it will go into the 27984 without coming too close to it, and if a number comes too close to it we had better choose the next less one; suppose, however, we try in this case 8 and we put the 8 in the quotient after the 3, and also to the right of the 9, the sum standing thus:

```
                548̇72 ( 38
                27
   98    2700    27872
```

We then multiply the 98 by the 8, and put the product under the 2700, the sum then standing thus:

```
             548̇72 ( 38
              27
   98  2700  27872
        784
```

By adding the 2700 and the 784 together, we get the correct divisor, which in this example, is the 3484; we then

```
                         •     548̇72 ( 38 quotient.
              trial divisor.   27
   98                    2700|  27872
                          784|
   correct divisor.      3484|  27872
                                .....
```

multiply the correct divisor by the 8 in the quotient and get 27872 which subtracted from the remainder of the first division which is the 27872, leaves nothing, hence the cube root of 54872 is 38.

Example. Extract the cube root of 145842732946

```
                                      .  .  .
                               5³  145842732946 ( 5263
         1st. trial divisor ☞      125
           152                7500 ‾‾20842
                               304|
  1st. correct divisor ☞      7804|  5608
           1566             811200‾‾5234732
                              9396|
  2nd. correct divisor ☞    820596:  4923576
           15783          83002800‾‾‾311156946
                             47349|
  3rd. correct divisor ☞  83050149|  249150447
                                  ‾‾‾‾62006499
```

To find the first two figures of the answer.

Beginning on the right hand, the figures are pointed off into threes, leaving 145 on the left; 5 is the nearest cube root of 145, and the cube of 5 is 125; place the 5 as the first figure of the quotient, and the 125 beneath the 145 and subtract, and bring down the next three figures, which are 842, making the remainder so far 20842, multiply the 5 by 3, (5 × 3 = 15) and put the 15 on a line with the 20842, but well to the left of it; multiply the 15 by the 5 (5 × 15 = 75), and put the 75 on a line with the 15 and add two ciphers to it thus getting 7500 as the trial divisor. As this trial divisor would go twice in the 20842 we put 2 in the quotient, and also after the 15 getting 152, which we multiply by the 2 and get 304, which we add to the 7500 and get 7804 as the correct divisor.

This correct divisor we multiply by the 2 in the quotient, getting 15608, which subtracted from 20842 leaves 5234 remainder. Then bring down the 732 thus getting the 5234732

To find the third figure of the answer.

Multiply the first two figures (52) in the answer by 3 (52 × 3 = 156) and place the 155 well out to the left. Add together the first correct divisor, the row of figures next above it, and the square of the last or right hand figure in the quotient, thus:

Row of figures next above the correct divisor	304
The correct divisor	7804
Square of the last figure (2) in the quotient	4
	8112

and this number, 8112, with two ciphers added on its right, is the trial second divisor. It will go 6 times, so put 6 in the quotient and 6 to the 156, making it 1566; multiply the 1566 by 6 = 9396; put this under the new or second trial divisor and add it to this new trial divisor, getting 820596 as the new or second correct divisor, which multiplied by the 6 in the answer gives the 4923576, which subtracted from the 5234732 leaves a remainder of 311156; bringing down the 946 we get 311156946.

To find the fourth figure of the answer.

Multiply the quotient, 516, by 3, thus getting 1578, which we place well out to the left. Add together the second correct divisor, the figures next above it, and the square of the last figure in the quotient, thus:

Row of figures next above the 2nd. correct divisor	9396
Correct 2nd. divisor	820596
Square of last figure, 6, in the quotient	36
	830028

This 830028 with two ciphers added is the new or third trial divisor, which we can see will go 3 times into the 311156946, so we put 3 in the quotient and also on the right of the 1578 getting 15783, which we multiply by 3 getting 47349, which we add to the third trial divisor and get the third correct divisor. This we multiply by the last figure, 3, in the quotient and place under the 311156949 and subtract, getting 62000499 remainder.

The answer is therefore 5263 with a remainder.

We may carry the answer into decimals to get it more nearly correct, by adding to the last remainder (62006499) three ciphers, and proceeding as below, thus:

```
                                    .  .  .
                              145842732946 ( 5263.7
        1st. trial divisor 5  125
        152            7500| 20842
                        304|
  1st. correct divisor ☞7804| 15608
       1566          811200| 5234732
                       9396|
 2nd. correct divisor ☞820596| 4923576
      15783        83002800| 311156946
                      47349|
 3rd. correct divisor ☞83050149| 249150447
      157897      8309750700| 62006499000
                     1105279|
 4th. correct divisor  8310855979| 58175991853
                                   3830507147
```

Multiply the quotient, 5263, by 3 giving 25789, which we place well out to the left. Add together the last correct divisor (83050149) and the row of figures next above it, (47349), and the square of the last figure (9) in the answer,

```
thus:    83050149
            47349
                9
         --------
         83097507
```

and then add to it two ciphers, thus getting the trial divisor which we see will go 7 times, hence we put a 7 in the quotient and also to the right of the 15789 making it 157897, we multiply by 7 and put it beneath the trial divisor and add it to it, thus getting the correct divisor which we multiply by 7 and then by subtraction get a remainder of 3830507147 to which we may add three ciphers and proceed as before to get the second place of decimals.

CALCULATION INVOLVING THE MEASUREMENT (OR MENSURATION) OF AREAS.

An area is a surface, either real or imaginary, and there fore has neither depth or thickness.

As the strengths of metals and the pressure of steam are usually stated in terms of the square inch, therefore the engineers calculations will mostly be in terms of the square inch.

A square inch is the surface enclosed within a square, the length of each of whose sides is an inch.

A circular inch is the area enclosed within a circle whose diameter is an inch.

A paralellogram is a figure whose opposite sides are parallel, as in the case of Figs. 91 and 92.

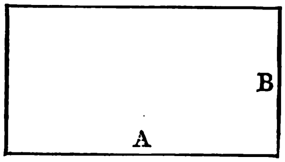


Fig. 91.

As all the angles in Fig. 91 are right angles it is also called a rectangular figure; while as its length is greater than its width it may also be called an oblong.

To find the area of a paralellogram multiply the length by

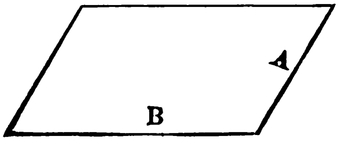


Fig. 92.

the breadth measured upon two edges that form an angle one to the other and meet, as do edges A and B in the respective figures.

A triangle is a figure having three sides and three angles, as D B and C, in Fig. 93. The base is the side on which it appears to stand, while the altitude or height is that of a vertical line drawn from the apex as dotted line A.

To find the area of a triangle.

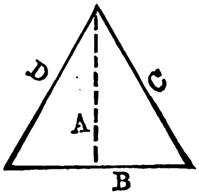


Fig. 93.

Rule. Multiply the length of the base by one-half the altitude or height.

A trapezoid is a "quadrilateral" or four sided figure which has two of its sides paralell, as in Fig. 94.

Its altitude or height is the distance between its paralell sides, as E in the figures.

To find the area of a trapezoid.

Rule. Multiply half the sum of the two paralell sides by the altitude.

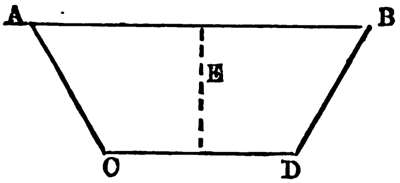


Fig. 94.

In an ellipse the line A, Fig. 95, represents the "major," and line B the "minor" axis. Line A is, however, sometimes termed the "conjugate," and line B the "transverse" axis or diameter.

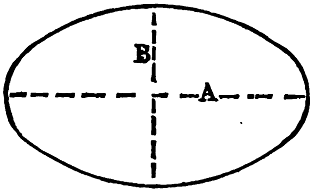


Fig. 95.

To find the area of an ellipse.

Rule. Multiply the length of the major by that of the minor axis and the product by 3.1416.

As steam pistons, pump plungers, pipes, bars of iron, and many other of the things with which the engineer deals, are circular, while their areas are usually measured in square inches, therefore, the most frequent application of the calculation of areas will be those involved in finding the area of circular surfaces, or enclosed within circles of a given diameter.

The simpler problems, however, are finding the areas of square or rectangular surfaces.

To find the area of a square or a rectangle.

Rule. Multiply the length in inches by the breadth in inches, and the sum will be the area in inches.

Or multiply the length in feet by the breadth in feet and the answer will be in feet.

Example. What is the area of a square each of whose sides measures 8 inches?

8 the length of one side.
8
64 the answer.

Answer 64 square inches.

In Fig. 96 we have a square representing a surface 8 inches square, and it is divided off into 8 vertical divisions and 8 horizontal divisions, or 64 in all; each vertical row contains 8 squares and there are 8 vertical rows, hence 8×8=64=all the squares.

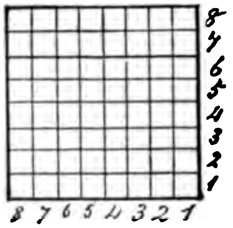


Fig. 96.

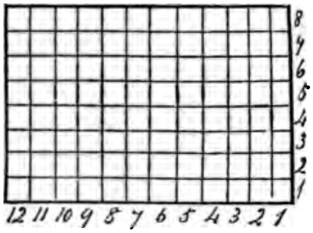


Fig. 97.

What is the area enclosed within a rectangle 12 inches long and 8 inches across?

inches.
12=the length.
8=the breadth.
96 the answer.

In Fig. 97 we have the rectangle with its length marked off into 12 divisions, and its width or breadth marked off into 8, giving 96 divisions in all.

Now suppose the surface is a taper, as in Fig. 98, and that it measures 2 inches long, half an inch wide at one end, and ne inch wide at the other, and we find its area by adding

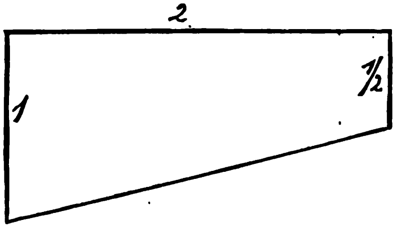


Fig. 98.

the width at each end together, dividing the sum by 2 and then multiplying by the length, thus:

inch.
1 width at one end.
.5 width at the other end.
2)1.5
.75
2 length.
1.50

Answer $1\frac{5}{10}$ or $1\frac{1}{2}$ inches.

To find the area, in square inches, of a circle of a given diameter.

Rule. Square the diameter and multiply by .7854

Example. What is the area of a circle whose diameter is 8 inches?

8 diameter.
8 diameter.
64 diameter squared.
.7854 proportion of a circle to a square.
256
320
512
448
50.2656

Answer 50 $\frac{265}{1000}$ square inches.

The reason for multiplying by .7854 will be perceived from Fig. 99, in which a circle is shown drawn upon a square, and

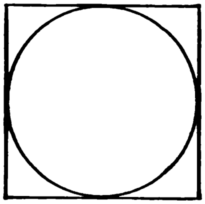


Fig. 99.

it is seen that in squaring the diameter of the circle we have obtained the area of a square of equal diameter.

Now .7854 bears the same proportion to 1 that the circle bears to the square, or, in other words, the circle encloses .7854 of the area of the square, hence after having squared the diameter we must multiply by .7854 in order to reduce the area obtained by squaring in the same proportion as a circle bears to a square having an equal diameter.

What is the area of a pipe whose diameter is 6½ inches?

```
     6.5
     6.5
    ----
     325
    390
    ----
    42.25
    .7854
   ------
    16900
   21125
  33800
 29575
 ---------
 33.183150
```

Answer 33.183 square inches.

What is the area of a washer whose bore is 10 inches and outside diameter 20 inches?

Here we have to deal with the circumferences of the outside and of the bore of the washer.

Now the circumference of a circle bears the same relation to the diameter that 3-1416 bears to 1, or, in other words, the ciecumference measures 7.1416 times the diameter; hence to find the circumference we multiply the diameter by 3.1416

Referring to Fig. 100, whice represents the washer, it will be perceived that its area may be obtained in two ways, first by taking the whole area enclosed in the outer circle, and then by subtracting the area of the bore from it; or second, by supposing the surface to be split along the dotted line *e* and opened out straight when the length of one side will equal the circumference of the outer circle, and that of the other side will equal the circumference of the inner circle representing the bore of the washer.

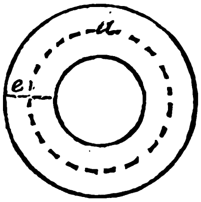


Fig. 100.

This is the simplest form to adopt, doing it, however, in this way·

Rule. Subtract the diameter of the bore from the outer diameter and divide the remainder by 2. Then add the quotient to the diameter of the hole and multiply by 3.1416 and by the difference between the bore and the outer diameter, or, in other words, the width.

inches.
20=outside diameter of the washer.
10=inside diameter of the washer.
2)10=difference between inside and outside diameter.
5=half of above difference.
10=inside diameter.
15=mean diameter of washer.

Then 3.1416 relation of circumference to diameter
15 mean diameter
157080
31416
47.1240 mean circumference.
10 width
area=471.2410

In subtracting the inside diameter from the outside diameter and adding half ot the difference between them to the inside diameter we have found a mean or average diameter which is represented in Fig. 100 by the dotted circle *a*.

CALCULATIONS INVOLVING THE MEASUREMENT OR MENSURATION OF SOLIDS.

A cube is a solid body having 6 sides whose lengths are equal, as in Fig. 101, which represents a cubic inch, each of its faces having an area of an inch.

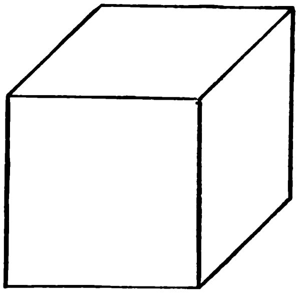


Fig. 101.

To find the solid contents of a cube we multiply the area of the end face by the length.

Example. What is the solid contents of a bar of iron 2 inches square and 24 inches long?

2
2
4
24
16
8
96

Answer 96 cubic inches.

What is the solid contents of a piece of round iron 4 inches in diameter and 12 inches long?

4
4
16 diameter squared.
.7854
64
80
128
112
12.5664 = area of end face.
12 = length of piece.
150.7968 = solid contents.

answer 150.7968 cubic inches.

In squaring the diameter we obtained the area the bar would have, supposing it to be square, as denoted by the dotted lines in Fig. 102, which enclose 16 squares, each representing a square inch.

The decimals .7854 are as much less than 1 as the area of a circle is less than that of a square, hence by squaring the diameter and by multiplying by .7854, we get the area of the end of the piece which multiplied by the length gives the contents.

Suppose a block of lead 1 inch square and 5 inches long, was drawn out into a round wire $\frac{1}{4}$ of an inch in diameter, how long would the piece of wire be if nothing was lost in the drawing process ?

As the wire is to have a diameter of ¼ inch, we first find the area of the end of the block expressed in square quarters

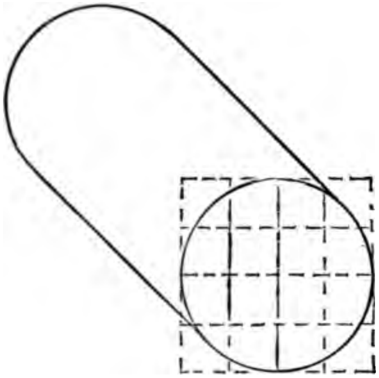


Fig. 102.

of an inch and then multiply by the length of the block which will give us the length the wire would be if it was to be square wire. Then by dividing by .7854, we increase the length in the same proportion, as the area of the round wire will be less than the area of the square wire, thus:

```
            4 [there are 4 quarters in an inch.
            4
           ---
           16 = area of block in square quarter inches.
            5
  .7854)80.0000(101.85
         78 54
        ------
          14600
           7854
          ------
           67460
           62832
           ------
            46280
            35370
            ------
              910.
```

answer 101.85 inches long.

We may understand the philosophy of this process from Fig. 103, in which the block is represented as divided off into ds, each ¼ inch square.

end face there are 16 of these squares, 4 rows with h row, so that multiplying the 16 by the length of

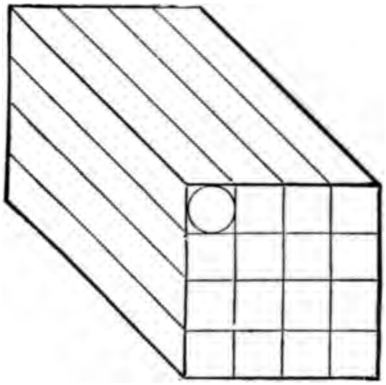


Fig. 103.

he block gives the length of square rods or square wire the lock would make, and we have to *increase* the length in the

```
            4
            4
.7854)16.0000(20.37
      15 708
        29200
        23562
          56380
          55978
            ··402

                 Then   2 0.3 7
                              5
                        1 0 1.8 5
```

ne proportion that the area of the round wire will be, less n that of square wire of an equal diameter, and this we accomplish by dividing by .7854, which is as much less than 1, as the area of a circle is less than that of a square of the same diameter as the circle.

In the example, we see that dividing the 80 by .7854 increased it to 101.85

We might square the diameter of the block, divide by the .7854, and then multiply by the length, and the answer would be the same as is shown in the second calculation of the example.

PART XIII.

ON THE MECHANICAL FORCES. THE LEVER; PULLEYS; GEAR WHEELS, ETC.

Power is Distinguishable from Force or Pressure in that the term power means force or pressure in motion, and since this motion cannot occur without the expenditure of the force or pressure, power may, with propriety, be termed the expenditure of force or pressure.

If We Suppose a piston to stand in a vertical cylinder sustaining a weight upon its surface and compressing the air within the cylinder, so long as there is no motion, no work is done as the term "work" is understood in a mechanical sense, and the weight merely produces a pressure. If, however, the weight be removed the compressed air will force the piston upward, performing a certain quantity of work which may best be measured by the amount of power exercised or expended.

The Mechanical Value of a given amount of power cannot be either increased, diminished or destroyed by means of any mechanical device or appliance whatsoever, through which it may be transmitted.

It may be concentrated, by decreasing the amount of its motion. It may be distended by increasing the distance through which it moves, or it may be expended in giving producing motion, but in either case, the amount of duty or work done is the exact equivalent of the amount of power applied.

A Gain or Increase in Speed is not, therefore, a loss of power, but merely a variation in the mode of using or utilising such power.

For instance, one lb. moving through a distance of 12 inches in a given time represents an amount of power which may be employed either as a 1 lb. moving a foot, 2 lbs. moving 6 inches, or ½ lb. moving through 24 inches, in the same space of time, the amount of the power or duty remaining the same in each case, the method of utilization merely having differed.

It is an Inexorable law of nature, that power is concentrated in proportion as the amount of its motion is diminished or distended in precise proportion as such motion is increased.

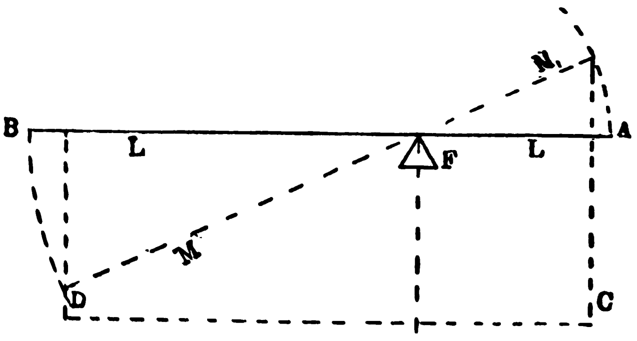


Fig. 104.

Suppose for Example, that in Fig. 104 L is a lever having its fulcrum at F, which is 4 inches from end A, and 8 inches n end B, and (leaving the weight of the lever out of the stion) if we place a 4 lb. weight on A, it will just balance s. at B.

If the Lever is moved, the amount of motion will be ice as much at end B as it is at end A.

If we apply the power at A, the lever has become a means converting 4 lbs. moving a certain distance, into 8 lbs. oving twice that distance, and nothing has been either ined or lost.

If we Apply the Four Lbs. at B, the lever has merely een used as a means of converting 4 lbs. moving a certain istance, into 8 lbs. moving one half that distance, and no-hing has been gained or lost.

Suppose That End A was moved an inch, and the power at that end will be 8 inch pounds or 8 lbs. moving an inch, whereas at the end B, the power is 4 lbs. moving two inches, we have therefore reduced the weight in the same proportion that we have increased the distance moved through.

Suppose now, that the lever is moved to the position denoted by the dotted line M M, and the leverages will be altered, that at end A becoming that denoted by the distance C, and that for end B being denoted by the distance D.

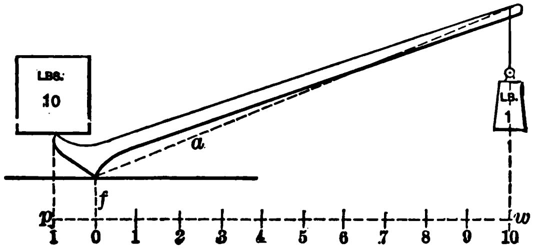


Fig. 105.

This Occurs Because we are dealing with gravity, which always acts in a vertical line.

A Crow Bar is an excellent example of the application o the lever. In Fig. 105 for example, we have a 1 lb. weig on the long end A of the lever, and as we are dealing wit weight the effective length of the long end of the lever i from the fulcrum *f* to W, which is divided into 10 equ divisions. The short end of the lever is from *f* to *p*, whic is equal to one division, hence the 1 lb. is balanced by the l lbs.

Suppose We Move the Lever into the position show in Fig. 106 and the 1 lb. will balance 22 lbs. at the other end,

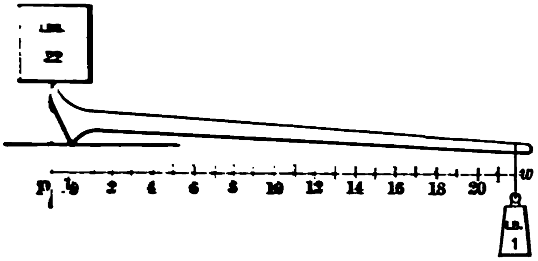


Fig. 106

because the force of the weights acts in a vertical line, and the leverage from O to *p* is 22 times that from O to *w*.

To Maintain Equal Leverage on the long end of the

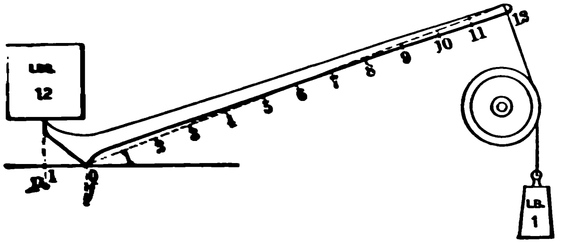


Fig. 107.

lever, we must apply the power at a right angle to its length. Thus in Fig. 107 the weight is passed over a pulley so placed that a cord passed over the pulley is at a right angle to the dotted line O, 12, this line passing straight from the fulcrum *f* of the lever to the point of attachment of the weight on the lever, and as the long end of the lever is twelve times as long as the short end, therefore the 1 lb. will balance 12 lbs. at the short end.

The Leverage Must be Measured in any case, in a straight line, but in this case that line, instead of being on a horizontal line, as when the weight was suspended vertically beneath its point of attachment, must be measured on a line from the fulcrum to the point of attachment, because the weight is applied at a right angle to the long end of the lever. In either case it is the effective length that is considered.

The Crow Bar used to move locomotives on the rail, is an excellent example of a lever with a rolling fulcrum, and in shape, is an admirable application of means to an end.

It Requires more power to move a piece of machinery from a state of rest, than it does to keep it in motion after it has started, and the shape of the crow bar is such, that it is a greater lever at first than it is afterwards, because its fulcrum moves backward as the bar is pushed downwards, we

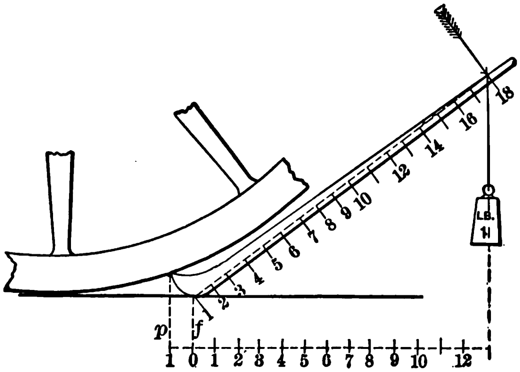


Fig. 108.

may also use it to further illustrate the difference between a suspended weight that acts in a vertical direction, and the application of a force at a right angle to the length of the lever.

The Long End of the lever in Fig. 108 has, if the power is applied at a right angle, as denoted by the arrow, a leverage of 18 to 1, whereas the weight has a leverage of 13 to 1.

When the Bar is Depressed to the position shown in Fig. 109 the 1 lb. has a leverage of but 9 to 1 (leaving the weight of the bar out of consideration).

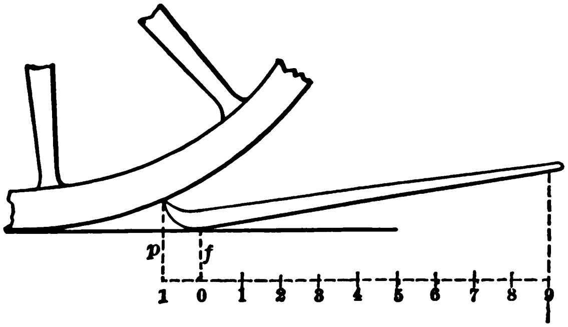


Fig. 109.

Here Then, the power applied is most concentrated at the time most concentration is required, in order to put the parts in motion, and the concentration gradually diminishes as the motion ensues, which is exactly what the circumstances require.

A Simple Method of distending power, is by means of pulleys or gear wheels. Suppose, for example, that in Fig. 110 we have a weight of 12 lbs. suspended from a shaft or drum, whose radius a is 10 inches, and that on the same shaft there is a pulley, whose radius b is 20 inches, and the two weights will balance each other.

In This Case the falling of either weight would not effect the leverage, because the distance of both weights would

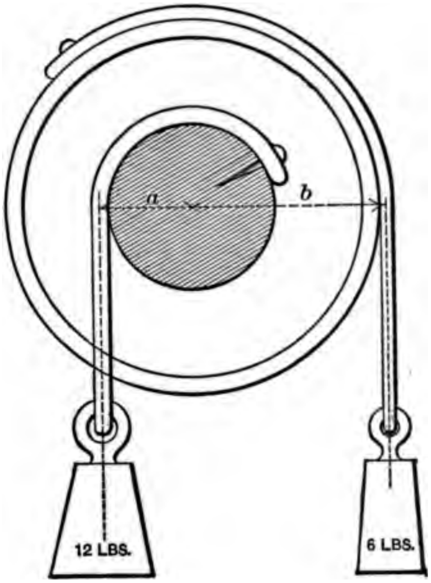


Fig. 110.

remain the same from the center of the shaft. The leverage of the 12 lbs. is denoted by the line A, and that of the 6 lbs. by *b*.

So far as the transmission of power is concerned, therefore, pulleys are in effect revolving levers, which may be employed to concentrate or to distend power, but do not vary its amount.

Suppose We Have Two Shafts on the first of which are two pulleys, B and C, Fig. 111, while upon the second there are two pulleys, D and E. A belt H connecting B to D. Let the pulleys have the following dimensions:

If we take the first pair of wheels B and C, we have that the velocity will vary in the same ratio or degree as their diameters vary, notwithstanding that their revolutions are equal.

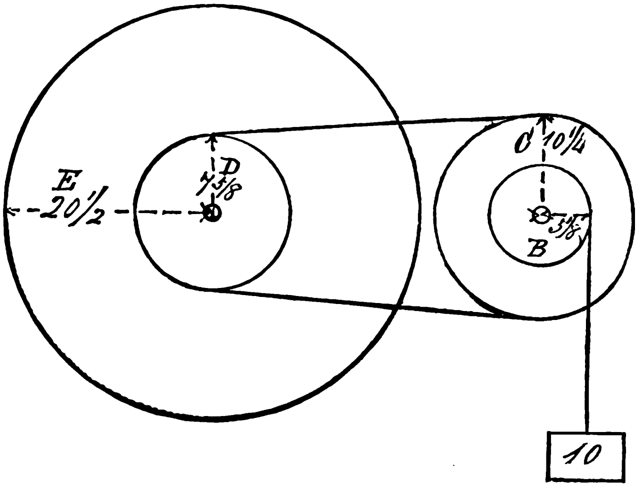


Fig. 111.

Radius.	Diameter.	Circumference.
B = 5⅛ Inches.	10¼ Inches.	32.2 Inches.
C = 10¼ "	20½ "	64.4 "
D = 7⅝ "	15¼ "	47.9 "
E = 20½ "	41 "	128.8 "

The Velocity is the length of the path moved through, and as it is the circumference of the pulley that is considered, the velocity of the circumference is that taken, thus if we make a mark on the circumferences of the two pulleys B and C, Fig. 111, the velocity of that on C will be twice that upon B, or in the same proportion as the diameters.

Let There Be suspended from the circumference of B

10 lbs. weight, and let us see the degree to which this power will be distended by this arrangement of pulleys, supposing the weight to rotate B, and making no allowance for the friction of the shaft.

Suppose the weight to have fallen 32.2 inches, and we have 10 lbs. moving through 32.2 inches, this power it will have transmitted to pulley B.

To Find what this becomes at the perimeter of C, we must reduce the number of lbs. in the same proportion that the perimeter of C moves faster than does that of B, hence we divide the circumference of one into the other, and with the sum so obtained divide the amount of the weight, thus circumference of C = 64.4 ÷ 32.2 (circumference of B), = 2 and 10 lbs. ÷ 2 = 5 lbs., which, as the circumference of C is twice that of B, will move twice as fast as the 10 lbs. at B, hence for C we have 5 lbs. moving through 64.4 inches.

Now C communicates this to D by means of the belt H, hence we have at D the same 5 lbs. moving through 64.4 inches.

Now E moves twice as fast as D, because its circumference is twice as great, and both are fast upon the same shaft, hence the 5 lbs. at D becomes 2½ lbs. at E, but moves through a distance equal to the circumference of E, which is 128.8 inches. To recapitulate then, we have as follows:

The weight	gives	10	lbs.	moving	through	32.2	inches.
Pulley B	"	10	"	"	"	"	"
" C	"	5	"	"	"	64.4	"
" D	"	5	"	"	"	64.4	"
" E	"	2½	"	"	"	128.8	"

That the Amount of Power is Equal in each case, may be shown as follows:

For C, 5 lbs. moving through 64.4 inches is an equal amount of power to 10 lbs. moving through 32.2 inches, because if we suppose the first pair of pulleys to be revolving levers, whose fulcrum is the center of the shaft; it will be plain that one end of the lever being twice as long as the other, its motion will be twice as great, and the 5 at 10¼ inches just balances 10, at 5½ inches from the fulcrum, as in the common lever.

In the Case of D we have the same figures both for weight and motion as we have at C, because D simply receives the weight or force, and the motion of C. In the case of E, we have the motion of the weight multiplied four times for the circumference of E is 128.8 inches, which divided by 4 gives 32.2 inches, which is the amount of motion of the weight, hence the 10 lbs. of the weight is decreased four times, thus 10 lbs. ÷ 4 = 3½ lbs., hence the 2½ lbs. moving through 128.8 inches, is the same amount of power as 10 lbs. moving 32.2 inches, and we may concentrate or convert the one into the other, by dividing 128.8 by 4 and multiplying the 5½ lbs. by 4, giving 10 lbs. moving 32.2 inches.

If, Therefore, we make no allowance for friction, nothing has been lost and nothing gained.

Thus Far we have taken no account of the time in which the work was done, more than as one wheel is caused to move by the other, and all of them by the motion of the weight they must all have began and also have to move at the same time. Suppose, then, that the time occupied by the weight in falling the 32.2 inches, was one minute, and the amount of power obtained, may be found by multiplying the lbs. of the weight by the distance it moved through in the minute, thus 10 lbs. moving 32.2 inches in a minute gives 32.2 inch lbs. per minute being the amount of power developed by the 10 lb. weight in lowerimg the 32.2 inches.

We may now convert the power at each pulley perimeter or circumference into inch pounds by multiplying the respective lbs. by the distance moved through in inches, as per the following table:

	Lbs.		Distance moved. Inches		Inch lbs. of power.
Weight at B	10	×	32.2	=	322
‘‘ ‘‘ C	5	×	64.4	=	322
‘‘ ‘‘ D	5	×	64.4	=	322
‘‘ ‘‘ E	2½	×	128.8	=	322

If We Require to find the power in foot lbs. per minute we divide by 12 (because there are 12 inches in a foot), thus 32 inch lbs. ÷ 12 = 26.83 foot lbs. per minute.

Now suppose that B was moved by a belt, with a pull of 10 lbs. at its perimeter, and made 100 revolutions in a minute, then the pull at the perimeters of C D and E would remain the same, but the motion would be 100 times as great, and the power would therefore be increased one hundredfold. It will be apparent then, that the time is as important an element as the weight.

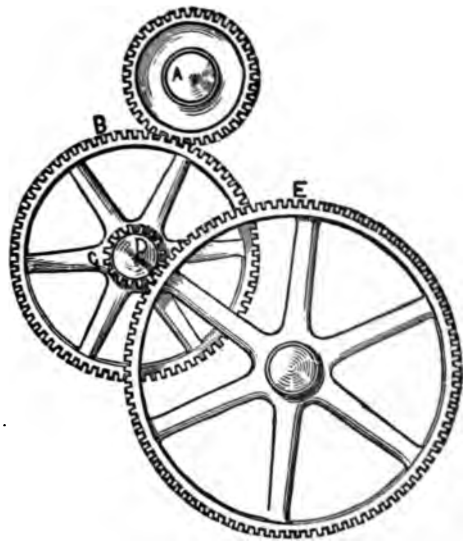


Fig. 112.

The Velocity and Power of Gear Wheels is calculated at the pitch circle.

Now suppose the gear A in Fig. 112 has 30, gear B 60, gear C 10 and gear E 80 teeth, and that 5 lbs. be applied at the pitch circle of A, and to find what this 5 lbs. would become at the pitch circle of E, we multiply it by the number of teeth in B and divide it by the number of teeth in C, thus:

	Lbs.
At pitch circle of A	5
Number of teeth in B	60
Number of teeth in C 10)	300
	30

Answer, 30 lbs. at the pitch circle of E.

Now Suppose that on the shaft of A there is a pulley 20 inches in diameter, and that on this pulley there is a belt exerting a pull of 5 lbs., while on the same shaft, there is a pulley 16 inches in diameter, and to find how much this latter pulley would pull its belt, we proceed as follows:

2) 20 = Diameter of pulley on A.
10 = Radius of pulley on A.
5 = Pull on pulley A.
Number of teeth in A = 30) 50 = Pull at center of shaft of A.
1.666
60 = Number of teeth on B.
Number of teeth on C = 10) 99.960 = Pull at axis of shaft of B.
9.996 = Pull at pitch circle of C.
80 = Number of teeth on E.
Radius of pulley on shaft of E 8) 799.680 Pull at axis of shaft E.
99.96 Pull at perimeter of last pulley.

We Have In This Case treated each pulley as a lever whose length equalled the radius of the pulley, while in the case of the wheel we have multiplied by the number of teeth when the power was transmitted from the circumference to the shaft, and divided by the number of teeth (the number of teeth representing the circumference), when the power was transmitted from the shaft to the teeth.

We Thus Find that power is composed of three things, first, the amount of impelling force, second, the distance that force moves through, and third, the time it takes to move that distance.

If we take a number of pulleys, say four, and arrange them one after another so that they drive by the friction of their circumferences, then the amount of power transmitted by each, will be equal, and the velocities will be equal, whereas, if we arrange them as in Fig. 111 the power will be equal for each, but the velocities or space moved through in a given time will vary.

What is Known as the Unit of Power, is the foot lb. being the amount of power exerted in raising or lifting one lb. one foot, and from what has already been said, it will be perceived that this is the same amount of power as 12 lbs. moving a distance of one inch.

Watt Determined that the power of a horse was equal to that necessary to raise 33000 lbs. one foot high, in a minute, and this is accepted, in English speaking countries, as being a horse-power.

An Engine or Machine has as much horse-power as it has capacity to lift 33000 lbs. a foot high in a minute.

The Piston and Crank of an engine form examples of the application of power to a lever of varying length, thus the effection leverage of the crank for a given position is found by drawing from the center line of the connecting-rod, a line at a right angle to that center line, and that passes through the center of the crank-shaft. Thus in Fig. 113 the effective leverage of the crank is represented by the line C, which is at a right angle to the center-line C of the connecting rod and passes through the center of the crank-shaft. The length of the other end of the lever is denoted by the length of the line *b*, which remains the same whatever the position of the crank may be, the center represents the fulcrum.

The position of the crank when at its greatest leverage, depends upon the length of the connecting-rod. Thus in Fig. 114 the crank is shown at half throw, and its effective leverage is denoted by the length of line *e*, which is less than the throw of the crank. In Fig. 115 its effective leverage is

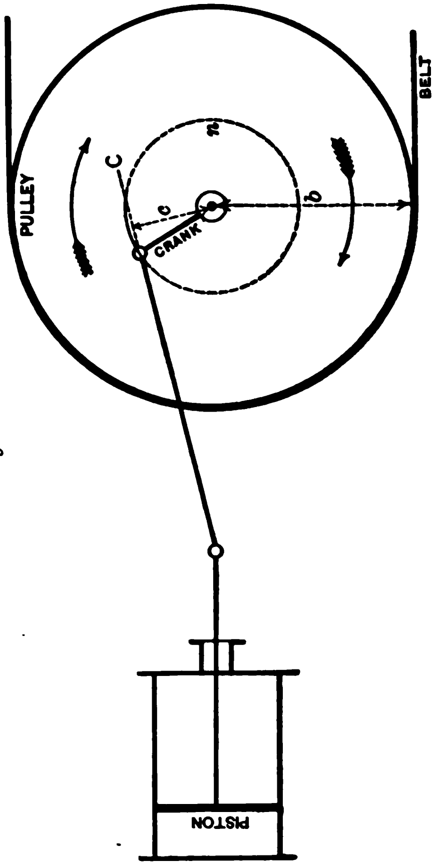


Fig. 113.

ıd by *c*, which is equal to the throw of the crank, is therefore at its point of greatest leverage.

longer the connecting-rod is, the nearer it will be to

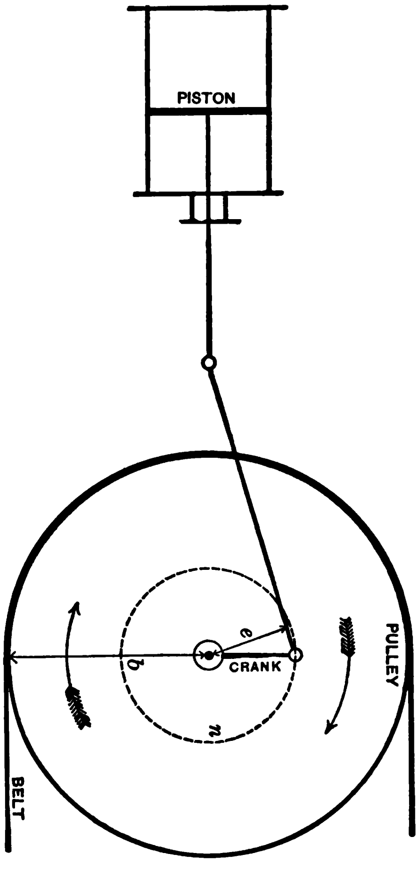
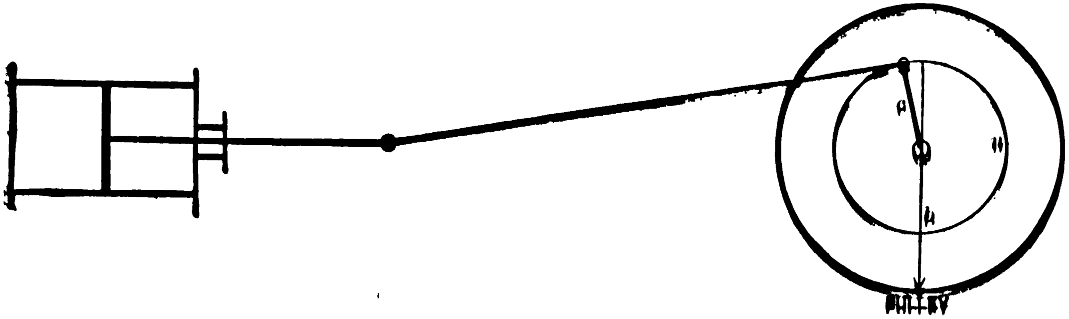


Fig. 114.

sition of half throw when at its point of greatest lever- ›ut this point will always be before the position of half ʳ for one piston-stroke, and after it, for the other.

Diagram showing how the Effective Leverage of the Crank is Influenced by the length of the Connecting-rod.

Fig. 115.



We might take the leverage of the crank in inches, for a number of positions so as to get its average leverage, and divide it into the radius of the pulley in inches, and this multiplied by the average pressure in lbs. per square inch, on the piston area, per revolution, and by the number of revolutions, would give us the number of inch pounds of power developed by the engine. This divided by 12 would give the foot pounds, and this divided by 33000 would give us the horse-power, allowing no loss from friction. This, however, is a round about way of doing it.

CALCULATING THE HORSE-POWER OF AN ENGINE.

The Horse-Power of an Engine may be calculated as follows:

Rule. **Multiply** the area of the piston by the average steam pressure upon the piston throughout the stroke, and by the length of the stroke in inches, which gives the number of inch lbs. received by the piston from the steam, during one stroke.

As There Are Two piston-strokes to one revolution of the engine, we multiply by two, and thus get the number of inch pounds received by the piston in one revolution.

By Multiplying This by the number of revolutions the engine makes in a minute, we get the number of inch pounds of power received by the piston in a minute.

By dividing this by 12, we get the number of foot pounds the piston receives per minute, and dividing this by 33000, we get the horse-power of the engine.

The 33000 is Obtained in this way. Watt determined that a horse was capable of exerting a power equal to the raising of 33000 lbs. one foot high in a minute, hence having foot-lbs. of the engine per minute, dividing then by 33000 gives the horse-power.

This Gives the amount of power received by the piston, but it is evident that the engine cannot exert so much power, because part of it is expended in overcoming the friction of the moving parts of the engine.

The amount of the piston power expended in overcoming the friction depends upon the fit of the parts upon the lubrication and the amount of the load.

Thus the friction of the cross-head guides, of the cross-head pin, of the crank-pin and of the crank-shaft bearings, will increase with the amount of resistance offered to the piston motion.

The Average Pressure on the Piston is a difficult thing to find however, for several reasons.

First, because the pressure in the cylinder may, during the live steam period, vary from that in the steam-chest because of the ports being too small or from the passages being choked from a defective casting.

Second, because the steam is wire-drawn during the time that the slide-valve is closing the port to effect the cut-off

Third, because the live steam in the port and passage at the time the cut-off occurs, gives out some power during the period of expansion.

Fourth, because there is some condensation of the steam in the cylinder after the point of cut-off, and there is no means of finding by calculation how much loss there may be from this cause.

During the Live Steam Period there is also loss from condensation in the cylinder, but this is made up for by steam from the steam-chest.

Fifth, the loss from condensation after the cut-off has occurred will vary with the speed of the engine, and is greater in proportion as the piston speed is less, because there is more time for the condensation to occur in.

Sixth, there is some pressure on the piston between the time that the exhaust begins and the piston ends its stroke.

Seventh, because the compression absorbs some of the piston power.

Assuming the Average Pressure on the piston to be known, however, we may calculate the horse-power as follows:

Example. What is the horse-power of an engine whose piston is 20 inches in diameter, and stroke 30, the revolutions per minute being 120, and the average pressure on the piston 60 lbs. per square inch?

```
                                              diameter of piston   20
                                              diameter of piston   20
                                      diameter of piston squared  4 00
                   .7 8 5 4
                       4 0 0
     area of piston=3 1 4.1 6 0 0 ☞ these two ciphers neglected.
                          6 0   average steam pressure.
lbs. pressure on piston 1 8 8 4 9.6 0 ☞ this cipher neglected.
                          3 0  length of stroke in inches.
                5 6 5 4 8 8.0 inch lbs. per stroke
                            2  two piston-strokes per revolution.
             12)1 1 3 0 9 7 6  inch lbs. per revolution.
                  9 4 2 4 8  foot lbs. per revolution.
                      1 2 0  revolutions per minute.
                1 8 8 4 9 6 0
                9 5 2 4 8
    3 3 0 0 0)1 1 3 0 9 7 6 0(3 4 2.7 2=horse-power of engine.
               9 9 0 0 0
               1 4 0 9 7 6
               1 3 2 0 0 0
                  8 9 7 6 0
                  6 6 0 0 0
                  2 3 7 6 0 0
                  2 3 1 0 0 0
                      6 6 0 0 0
                      6 6 0 0 0
```

In Working Out the Calculation, the ciphers that are decimals and are on the right hand are neglected or taken no account of, because they represent no value and may therefore be discarded.

Thus the area of the piston is 314$\frac{16}{100}$ feet, the two right hand ciphers having no value. Again the lbs. pressure on the piston is 18849$\frac{6}{10}$ lbs., and the right hand cipher having no value is discarded. The inch lbs. per stroke is 565488, and the decimal cipher representing nothing is discarded when multiplying by the 2.

We Have in This Case taken no account of the fact that the piston-rod prevents the steam from acting against a part of the piston area during one stroke, hence for correct results, we must subtract from the area of the piston one half the area of the piston-rod.

The Horse-Power Thus obtained is that which the engine receives from the steam, and is more than the engine is capable of exerting to drive machinery, because a part of this power is consumed in overcoming the friction of the working parts of the engine.

TESTING THE HORSE-POWER OF AN ENGINE.

The Useful Horse-Power of a Stationary Engine may be readily and accurately obtained by means of a pair of scales, and a brake, as shown in Fig. 116, which is constructed and used as follows:

On the Crank-Shaft of the engine is a pulley enveloped by a friction brake, which consists of an iron band, to which wooden blocks are fastened.

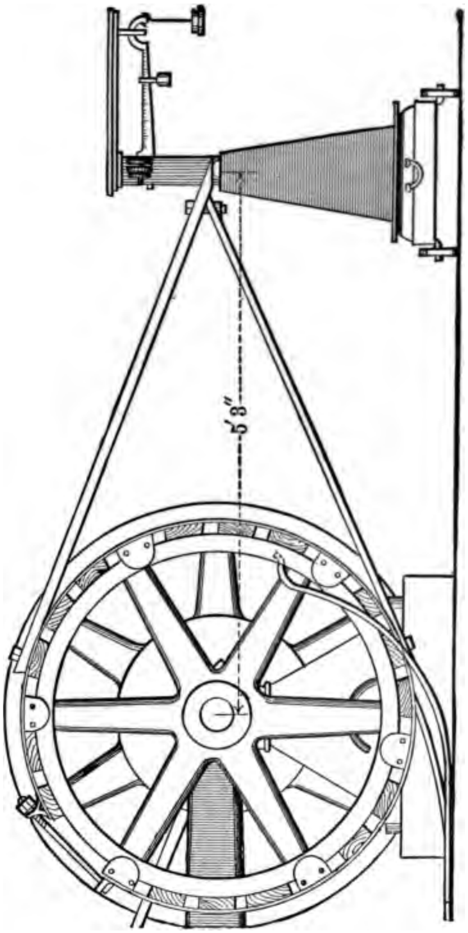


Fig. 116.

Friction Brake for Testing the horse-power of an Engine.

The Ends of the Iron Band do not meet, but ar
cured together by a bolt as shown.

By screwing up the bolt, the wood blocks are broug
press against the circumference of the wheel.

This Forms a friction brake that would revolve wit wheel, were it not for two arms that are secured to the brake, and rest at the other end upon a block placed upon a pair of scales.

The Principle of Action of this device is, that the amount of friction between the brake and the wheel is weighed upon the scales, and this amount multiplied by the velocity of the wheel at its circumference and divided by 33000, is the horse-power of the engine.

It is Necessary, in Arranging this brake, to have its end rest upon the scale at the same height from the floor as the center ot the crank-shaft, so that the line marked 5′ 3″ (5 feet 3 inches), which represents the length of the lever, shall stand parallel with the surface of the platform of the scale.

To Test the Horse-Power we proceed as follows:

Suppose the pressure of the end of the lever on the scale is found by the weight on the scale beam to be 540 lbs., the diameter on which the brake blocks act being three feet, the length of the leverage being 5 feet 3 inches, as marked, and the engine making 154 revolutions per minute, and the calculation is as follows:

```
                              5 40 lbs. on scale.
                              5.25 leverage in feet.
                             ------
                             27 00
                            108 0
                           2700
                           -------
radius of pulley in feet 1.5)2835.00 (1890 lbs. at pulley perimeter.
                           15
                           ---
                           133
                           120
                           ---
                            135
                            135
                            ---
                            · · ·0
```

```
then      3.1416
               3 diameter of pulley in feet.
          ------
          9.4248 circumference of pulley in feet
             150 revolutions per minute.
        --------
        471.2400
       94248
      ----------
      1413.7200 velocity of pulley perimeter.
           1890 pounds at pulley perimeter.
    ------------
     12723480
    1130976
    141372
33000)2671930.80(80.9
    264000
    ------
      319308
      297000
      ------
       223080
       ======
```

Answer 80$\frac{9}{10}$ horse-power.

In This Calculation we have nothing to do with the size of the cylinder or the steam pressure, because the scale beam tells us how many lbs. the brake exerts on the scale, and we treat the brake and brake pulley as levers. Thus by multiplying the lbs. on the scale by the leverage of the brake arm, we get the number of lbs. exerted at the center of the crank-shaft, and by dividing this by the radius of the brake pulley, we get the number of lbs. on the circumference, or what is the same thing, at the perimeter of the brake pulley.

By Multiplying the Circumference of the pulley in feet by the revolutions per minute, we get the speed at which the above pounds travel, and by multiplying this speed by the number of lbs. we get the foot pounds, which divided by 33000 gives us the effective horse-power of the engine

This Effective Horse-Power is correct, because in loading the engine by the brake, the crank-pin, cross-head guides, etc., are all placed under the same friction as they would be if it was a circular saw, or some other piece of machinery or machine that the engine was driving.

SAFETY-VALVE CALCULATIONS.

Among the most Frequent questions asked in an engineers examination, are those relating to the safety-valves of boilers.

These questions may be easily answered from a study of the following:

The Safety-valve is a Device for relieving the boiler of steam after it has reached a certain pressure.

This it Accomplishes by letting the steam escape after it has reached the required pressure.

At what pressure the safety-valve will blow off depends upon the position of the weight on the safety-valve lever.

The Calculations referring to this part of the subject are finding how much weight will be required to be placed at a given point on the lever, in order with a given sized valve to blow off at a given pressure.

Finding the Position on the lever of a given amount of weight in order to blow off at a certain pressure.

Finding, with a given sized Valve and a given weight, how to mark off the lever and where the notches must be cut for given pressures.

In each of these Calculations there are three elements; first, the area of the valve and the steam pressure, which constitute the effect of acting to lift the valve; second, the amount of the weight and its position upon the lever, which acts to keep the weight closed; and third, the weight of the lever and of the valve, which acts to keep the valve closed.

In Fig. 117 we have a Drawing of a Safety-valve shown in section, and if there was no weight upon the lever, the pressure of steam the valve would hold in the boiler, would be that due to the weight of the valve and of the lever upon the valve.

To find out how much this would be, we would have to put the valve itself and the pin A on a pair of scales and weigh them

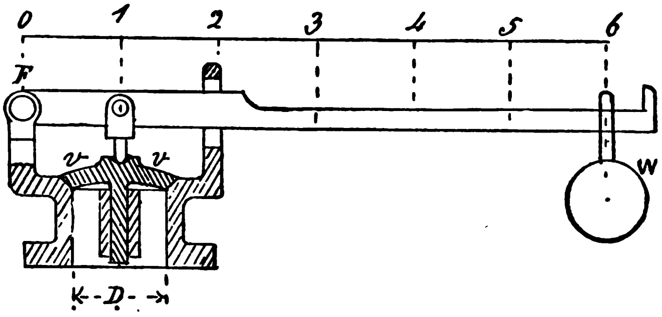


Fig. 117.

Then put a piece of string through the hole at B in the lever, and see how much it weighed when suspended from that point.

Suppose the valve to weigh 2 lbs. and the lever 10, and the total will be 12 lbs.

Next we find the area of the valve, and suppose this to be 3 square inches, then we may find how much pressure the valve would keep in the boiler, by dividing the area of the valve into the weight holding the valve down, thus:

	lbs.
weight of valve	2
" " lever	8
area of valve 8)	10
pressure the valve would hold	7.25 lbs.

The Area of the Valve is that part of its face receiving the steam pressure when the valve is seated, so that if the smallest part of the valve arm is equal to the diameter of the seat bore, the diameter from which the valve area is to be calculated, will be that denoted by D in the figure, and cannot in any case, be less than this, But if the smallest end of the valve cone is of larger diameter than the smallest end of the seat cone (which should not, but might be the case), then it is the smallest area of valve cone that must be taken in calculating the area, because that is the area the steam will press against.

Now suppose we rest a 20 lb. weight on the top of the valve that is on the line denoted by 1, and there will be 32 lbs. holding the valve down, thus, weight of valve 2 lbs., of lever 10, and weight added 20 lbs., and to find how much pressure this would hold in the boiler we divide it by the valve area thus:

$$\text{valve area} = 8\,)\,\overset{\text{weight on valve.}}{\underline{32}}$$
$$4 = \text{pressure valve will hold.}$$

But suppose we put the weight on the lever, in the position shown in the figure, which is six times as far from the valve as the fulcrum F of the lever is, and its effect on the valve will be six times as great as it would if placed directly upon the valve, so that leaving the weight of the valve, and of the lever out of the question (as is commonly done in engineers examinations), we may find out what pressure the valve will hold, as follows:

Rule. Divide the length of the lever by the distance from the center of the valve to the center of the fulcrum. Multiply by the amount of the weight in lbs., and divide by the area of the valve.

Example. The area of a valve is 8 inches, the distance from the center of the fulcrum to the center of the valve is 4 inches, and the distance from the fulcrum to the point of suspension of the weight 24 inches, the weight is 40 lbs., what pressure will the valve hold?

length of lever.
from fulcrum to valve 4)24
6
40 amount of weight.
area of valve 8)240
30

lbs. per square inch the valve will hold = 30

The Philosophy of this is clear enough, when we consider that as the weight is six times as far from the fulcrum as the valve is, and each 1 lb. of weight will press with a force of 6 lbs. on the valve, hence the 40 lbs. will press 240 lbs. on the valve, and as the valve has 8 square inches the 240 become 30 lbs. for each inch of area.

Example. The area of a safety-valve is 8 inches, the distance from the fulcrum to the valve is 4 inches, and the weight is 40 lbs., how far must the weight be from the fulcrum to hold in the boiler a pressure of 30 lbs. per square inch?

inches. lbs.
from fulcrum to valve. 4) 40 amount of weight.
10

area of valve 8 square inches.
pressure required. 30
10) 240
24

answer = 24 lbs. per square inch.

Example. The diameter of a safety-valve is 4 inches, the distance from the center of the fulcrum to the valve is 3 inches, a 50 lb. weight is 30 inches from the fulcrum, what pressure will the valve hold?

```
      3 diameter of valve.
      3
     ---
      9
  .7954
  -----
     36
    45
   81
  63
  ------
  7.1586 = area of valve.
```

```
          3)50
            --
            16.666
                50
            ------
   7.158)833.300(116.26
         7158
         ----
         11750
          7158
         -----
          45920
          42948
          -----
           19720
           14316
           -----
            54040
            42948
            -----
            11092
```

answer 116.26 lbs. per square inch.

PART XIV.

HEAT; WATER; STEAM.

The Heat Unit, or the unit whereby heat is measured, is the quantity of heat that is necessary to raise 1 lb. of water from its freezing temperature (which is 32 degrees Fahrenheit) one degree, and this unit is sometimes termed a *thermal unit.*

The Reason That some Specific Temperature, as 32 degrees Fahrenheit, is taken, is because the quantity of heat required to heat a given quantity of water 1 degree, increases with the temperature of the water, thus it takes more heat to raise 1 lb. of water from 240 to 245 degrees, than it does to raise it from 235 to 240, although the temperature has been raised 5 degrees in each case.

The Whole quantity of Heat in Water or steam is not, however, sensible to the thermometer, or in other words, is not shown by that instrument, the heat not so shown or indicated, is termed *latent* heat.

Water Obtains Latent Heat while passing from a liquid to a solid state, as from water into ice, and while passing from a liquid to a gaseous state, as while passing from water into steam, and the existence of latent steam may be shown as follows:

If we Take a Body of Water at a temperature above freezing, and insert therein a thermometer, the decrease in the temperature as the water becomes frozen, will be shown by the thermometer. If then, its temperature being say at zero, heat be continuously imparted to the ice the thermometer will mark the rise in temperature until the ice begins to melt, when it will remain stationary at 32 degrees so long as any ice remains unmelted, and it is obvious that all the heat that entered the water from the time the ice began to melt, until it was all melted became latent, and neither sensible to the sense of feeling nor to the thermometer. Similarly, if the water, after the ice is all melted, be heated in the open air, the thermometer will mark the rise of temperature until the water boils, after which it will show no further rise of temperature, although the water still receives heat. The heat that enters the water from boiling, until it is evaporated away, is the latent heat of steam. The latent heat of water is 143° Fahrenheit, and that of steam when exposed to the pressure of the atmosphere, or under an atmospheric pressure of 15 lbs. (nearly), is 960°, which may be shown as follows:

If a Given Quantity of Water, as say 1 lb., has imparted to it a continuously uniform degree of heat sufficient to cause it to boil in one hour, then it will take about 5⅓ more hours to evaporate it all away, hence we find the latent heat by taking the difference in the amount of heat received by the water, and that shown by the thermometer thus:

	degrees.
temperature by thermometer at boiling point	212
less the temperature of the water at first	32
heat that entered the water in the first hour	180
hours that the water was subsequently heated	5⅓
	900
one third of 180 =	60
heat that entered the water during the 5⅓ hours	960 degrees.

This, however, is not quite correct, as it would take slightly more than 5⅓ hours to boil the water away and the heat that entered the water after it commenced to boil, would be about 966 degrees.

If the steam that arose from the water while it was boiling were preserved without increasing the pressure under which it boiled, and without losing any of its heat, it will have a temperature the same as that of the water from which it was boiled, which is a temperature of 212°, so that neither the steam nor the water account, by the thermometer, for the 966 degrees of heat that entered the water after it boiled, hence the 966° became latent, constituting the latent heat of the steam when boiled from and at a temperature of 212°.

The Total Heat of Steam is the sensible heat, or that shown by the thermometer, added to the latent heat, hence the heat necessary to evaporate water into steam at a temperature of 212° (which corresponds to a pressure of 14.7 lbs. per square inch), is 212° + 966° which is 1178°, and these, therefore, are the number of degrees that must be imparted by the coal to the water, in order to form steam at a temperature of 212°.

WATER.

Water is at its Greatest Density when at a temperature of 39.1 degrees Fahrenheit, that is to say, it occupies its least space and weighs the most per given quantity (as per cubic inch), when at that temperature.

At a lower temperature water expands, its freezing point being 32° Fahrenheit, below which it forms ice. The weight of a cubic foot of water when at its maximum density (39.1), is 62.382 lbs. Water also expands as its temperature is increased above 39.1 degrees, thus while it is heated from 39.1 to 212°, its volume increases from 1 to 1.04332. The expansion for each degree of heat added to its temperature, increases from 0 at 40° Fahrenheit to .0044 at 212°.

The Rate of Expansion of Water at a temperature above 212 is unknown.

STEAM.

At Every Temperature above freezing point water passes from the liquid into a gaseous state, the gas being termed steam. While water is below its boiling point its evaporation occurs at its surface only, but when its mass is heated to boiling point, and additional heat is imparted to it, evaporation occurs from the water lying against the surface from which it receives the heat, and an ebbulition is caused by the vaporized water passing through the mass, the ebbulition being what is known as boiling.

The Temperature at Which Water Boils depends upon the pressure acting upon its surface, the boiling point being at a lower temperature in proportion as the pressure is reduced, thus water at the top of a mountain, where the pressure of the atmosphere is less than at the sea level, would boil at a lower temperature than 212°, which is the boiling point when the atmospheric pressure is 14.7 lbs., which it is assumed to be at the sea level. Conversely, the boiling point is raised in proportion as the pressure upon its surface is raised whether that pressure consists of air or of steam. As, however, the pressure is increased, the boiling point is at a higher temperature. So long as the steam is in contact with the water both are at the same temperature, as denoted by the thermometer (although they do not contain the same quantity of heat, as will be shown presently), and the steam is termed *saturated* steam.

The Pressure of Saturated steam cannot be either increased or diminished without either increasing or diminishing its temperature, hence there is a definite relation of pressure to temperature, which enables the pressure to be known from the temperature, or conversely, the temperature to be known from the pressure. But if the steam be separated from the water it may be what is termed *super-heated*, which is that it may be sur-charged with heat or contain more heat than saturated steam at the same pressure, such additional heat, however, is latent.

The Pressure of Steam is the lbs. of force it exerts upon a given area, as upon a square inch. In non-condensing engines the effective pressure of the steam is its pressure above that of the atmosphere, because the exhaust side of the piston being exposed to the atmosphere receives the atmospheric pressure, which must be overcome by a corresponding pressure of steam on the steam side of the piston, and this pressure is not, therefore, available for producing work or power in the engine.

In Condensing Engines, however, the exhaust side of the piston is (as nearly as practicable), relieved of the atmospheric pressure, and assuming a perfect vacuum to be formed the whole of the steam pressure is exerted to propel the piston, in which case the steam pressure is termed the *absolute* pressure.

In considering the weight or density or the expansion of steam its *absolute*, and not its effective pressure must obviously be taken.

What is Termed Dry Steam is *saturated* steam that does not contain, what may be termed, entrained water, which is water held in suspension in the steam, which may be caused by the surface of the water through which the steam is allowed to rise, being too small in proportion to the volume of steam formed, in which case the rapid passage of the steam through the water causes it to carry up water with it and [illegible] expansion, this action being termed *foaming* or *priming*.

Suppose, for Example, that a boiler be filled with water up to the bottom of the steam dome, then all the steam formed would require to find exit from the water within the area of the dome, and the violence of the ebullition would cause [illegible]. [illegible] then to obtain dry steam there must be provided a sufficient area of water surface for the steam to pass [illegible].

The Water so Entrained is evaporated into steam if the steam is wire drawn, that is allowed to expand and reduce in pressure.

THE EXPANSION OF STEAM.

A Cubic Inch of Water when evaporated into steam at a [illegible] lbs. per square inch, occupies as steam, a space or volume of [illegible] cubic inches, and its weight will be [illegible] that of the water from which it was evaporated.

If Additional Heat be imparted (after its evaporation [illegible] steam), such additional heat becomes latent and does [illegible] cause an increase of sensible temperature, or of pressure.

The Weight of a Given Volume of Steam, therefore, [illegible] a definite and constant relation to the pressure and [illegible] temperature of the steam, so that the pressure or [illegible] temperature being known, the weight of a given [illegible] as say a cubic foot may be known therefrom. Or the weight of a cubic foot of steam being known, its sensible temperature and pressure may be known therefrom.

This Would Not be the case if steam expanded by heat. Suppose, for example, we have a cubic foot of steam at any absolute pressure as say 15 lbs. per square inch, a cubic foot weighing [illegible] of a lb., and its sensible temperature will be

213°. Now it is evident that the weight will remain the same whatever the amount of heat that may be imparted to the steam. Now if the steam were maintained within the cubic foot of space, and was capable of expansion by the absorbtion of additional heat, its pressure would increase and its weight remaining the same there would be no definite relation between the weight and the temperature and pressure.

But If the cubic foot of steam were allowed to expand, so as to occupy more space, then additional heat is necessary to prevent its condensation.

The Relation Between the Temperature, Pressure, and Weight of Steam is not quite proportional to the volume, because steam is not a perfect gas and does not therefore, strictly follow Marriott's law.

A Perfect Gas is one, that during expansion or compression, follows the law laid down by Boyle and Mariott, this law being that if maintained at a constant temperature, the volume is inversely proportional to the pressure.

For Example, the quantity of gas, that if confined in a cubic inch of space, would give a pressure of 80 lbs. per square inch, would give a pressure twice as great (or 160 lbs. per inch of area), if confined in one half the space, that is if compressed into one half of a cubic inch. Conversely, if the cubic inch was allowed to expand until its pressure was 40 lbs., it would occupy two cubic inches of space. Assuming, of course, that the temperature remains the same. Since, however, if a gas be compressed, its temperature is increased by reason of the friction of the particles moving one upon the other, the law of Marriott may be better explained as follows:

Suppose We Have three vessels, A, B, and C filled with a fluid which is a perfect gas, the temperatures being equal.

Let the pressure be: A 40, B 80, and C 160 lbs. per square inch, then 2 cubic inches of the fluid in B, will weigh the same as 4 cubic inches in A, because that in B is at twice the pressure of that in B, and the 2 cubic inches in B will weigh the same as 1 cubic inch in C, although its pressure is one half that of C, or what is the same thing, whatever number of cubic inches of the fluid in C it takes to weigh a pound, it will take twice as many in B, and four times as many in C to weigh one pound.

But Steam is Not a Perfect Gas, as is evidenced by the fact that its volume does not increase in a ratio inverse to its pressure. For example, if a cubic inch of water be evaporated into steam at a pressure of 14.7 lbs. per square inch, its volume will be 1644 cubic inches, and its temperature 212° Fahrenheit.

But If the cubic inch of water be evaporated into steam at twice the pressure, which is 29.4 lbs. per square inch, its volume will be 838 inches.

The Volume then is not inversely as the pressure, although the actual quantity and weight remain the same, as is proven by the fact that if the steam at either pressure were condensed it would pass back into the cubic inch of water from which it was generated.

This May Be Accounted for in the difference in the boiling point of the water in the two pressures, or in other words, by the difference in the temperatures, thus the boiling point of the water at a pressure of 14.7 lbs., is 212°, while that for the pressure of 29.4 is increased about 38.4 degrees, and the steam is at the higher pressure expanded by these 38.4 degrees of heat, which adds to its pressure, although not effecting its actual quantity or weight.

The Amount of this expansion may be estimated as follows:

Taking the 1644 cubic inches, and supposing the steam to be a perfect gas, we divide it by 2 to obtain half the volume, 1644 ÷ 2 = 822.

If then we subtract this 822, which is the volume of the steam if it acted as a perfect gas, from the 838 it actually occupies, we get 16 (838 — 822 = 16), which is the number of cubic inches of expansion due to the increase in the boiling temperature.

THE CONVERSION OF HEAT INTO WORK.

When Steam performs work a certain portion of the heat it contains is converted into work, the steam simply being a medium of conveying the heat into the cylinder in which the motion of the piston converts this proportion of heat into work. It has been proven that a given quantity of heat will pass into a given quantity of work, and conversely that a given quantity of work is convertible into a given quantity of heat, and it has also proven that so much heat is convertible into so much work, independent of the temperature of the heat during its conversion into work, power or energy, all three of these words being used to imply pressure, force, or weight in motion.

The Accepted Measurement of the conversion of heat into work is known as *Joule's equivalent.*

Joule having determined that the amount of power exerted in raising 772 lbs. one foot, is the equivalent of the amount of heat that is required to raise the temperature of 1 lb. of water, when at or near its freezing point (that is at a temperature of 39.1°) one degree.

This is Called *Mechanical equivalent of heat*, being merely the quantity of heat necessary to do a certain amount of work, but having no relation to the time in which that work was done.

The Conversion of Heat into Work and of work into heat, may be demonstrated as follows. Suppose a cylinder to be so situated that heat can neither be transferred to it or from it, and that saturated steam be admitted under the piston so as to fill one half of the cylinder at a pressure of 50 lbs.

Suppose Then, that we raise the piston from an independent application of power, the steam simply expanding to fill the space given by the piston, but not exerting its force to move the piston.

Now Suppose the experiment is repeated, permitting the force of the steam to lift the piston, and the temperature of the steam will be less in the second than it was in the first, proving that in the second experiment a certain portion of the heat in the steam was converted into the work of raising the piston.

If We Desire to reconvert the work into heat, we may force the piston back again to its original position, and its temperature will be restored to what it was before we allowed it to raise the piston. It is here, of course, assumed that there is no friction in moving the piston in the cylinder.

The Apparent or External work performed by steam, in expanding and moving a piston against a given resistance, is measurable by multiplying the amount of the resistance against which the piston moved, by the distance it moved through, thus:

Suppose a Piston weighs 100 lbs., and had resting upon it a weight of 50 lbs., and that it be raised by the expansive action of steam a distance of a foot, then since the total re-resistance it moved against would be (supposing it to move frictionless in the cylinder) 150 lbs., and since the amount of motion was one foot, the external or apparent amount of work performed by the steam will be 150 foot lbs. or 150 lbs. moved one foot.

But in Expanding the steam has performed a certain amount of what is called *internal* work, that is to say, its particles or atoms have done work in expanding, and this work has been done at the expense of some of the heat in the steam, so that the loss of heat due to the motion of the piston, is the amount of heat converted into work in moving the piston against the piston resistance, added to that converted into the internal work, due to the expansion of the steam.

It is Because of this internal work, that the steam in expanding, does not strictly follow Marriotte's law.

The Mechanical Theory of Heat is, that the atoms of which bodies are composed, are at absolute rest when at a temperature of 461.2° below the zero of Fahrenheit, which is supposed to be absolute cold and at any degree of temperature above this, the atoms are in motion; the extent and force of their motion determines what we know as the temperature of the body.

Atoms Are Capable of Transmitting their motion to adjoining atoms of the same, or of other bodies, losing of course, the amount of motion they transmit, and it is in this way that heat is conveyed from one to another part of the same body, or from one body to another, this being known as the heat of *conduction.*

But Heat May be conveyed by means of what is known as *radiation*, and also by *convection.*

Thus, the Air surrounding a heated body becomes heated, and by reason of its expansion it then becomes lighter, and rises, a fresh supply of cooler air taking its place, becoming in turn heated, and again giving place to cooler air, the heat thus conveyed away by the fluid or air, is conveyed by what is termed *convection.*

Heat Also Passes from a body in straight lines or rays, which do not heat the air through which they pass, to their own temperature, but do impart that temperature to a solid body, as iron or water; the heat that passes from a body in this manner is termed radiant heat, or the heat of *radiation*.

In the Cylinder of a Steam Engine, therefore, the heat contained in the steam is disposed of as follows:

A Certain Portion of it is converted into work through the medium of the piston

Another Portion is conveyed away by the walls of the cylinder. this portion including the heat of convection and that of radiation.

Yet Another Portion is converted into internal work. Referring to the latter, suppose that steam is permitted to expand and its atoms will be in motion, which motion has been derived at the expense of or from the conversion of a certain quantity of heat.

The Amount of the heat so converted, obviously depends upon the amount of the motion. Suppose, for example, that steam is generated in a closed vessel as in a steam boiler and that a certain pressure having been attained, the steam is permitted to pass off as fast as it is formed from the boiler, then the amount of atomic motion will remain constant, because the pressure remains constant; but suppose instead of the steam passing off, it be confined within the boiler, then the pressure will increase and there will be a greater risestance to the motion of the atoms, hence their motion will be less, and less of their heat will therefore be converted into atomic motion. and as a consequence, more of it will exist in the form of sensible heat, hence while the pressure of steam continues to increase. its heat is increased, not only by reason of the heat it receives from the furnace, but also by reason of that abandoned by the steam. because it is prevented by the pressure from expending it in atomic motion.

PART XV.

THE INDICATOR.

The Indicator is an instrument which marks or draws a figure or diagram as it is called, which shows the pressure there is in the cylinder at every point in the piston stroke, while it also shows the resistance offered by the same body of steam, to the piston on its return stroke. From the form of this figure or diagram, the engineer is enabled to discover whether those parts of the engine whose operation regulates the admission of the steam to and its exhaust from the cylinder are correctly adjusted.

From the Diagram the Engineer may find the average or mean effective pressure of steam on the piston throughout the stroke, for use in calculating the power of the engine.

He May Also locate the point of cut-off, of release, the amount of back pressure, the degree of perfection of the vacuum in a condensing engine, and the amount of compression.

From the Area of the Diagram the engineer may also estimate the quantity of steam that is used, and supposing it to be dry steam, he may calculate the amount of water used to make the steam, and assuming one pound of coal to evaporate so much water, he may calculate the amount of coal used to produce the steam.

The Indicators commonly used upon steam cylinders contain two principal mechanical movements; first a drum revolving the piece of paper upon which the diagram is to be marked, and second, a piston and paralell motion for moving the pencil to mark the diagram upon the revolving paper.

The Drum is given a motion that, to insure a correct diagram, is exactly timed with the piston motion.

The Pencil is given a vertical movement; this movement must bear a constant and uniform relation to the pressure of the steam in the engine cylinder.

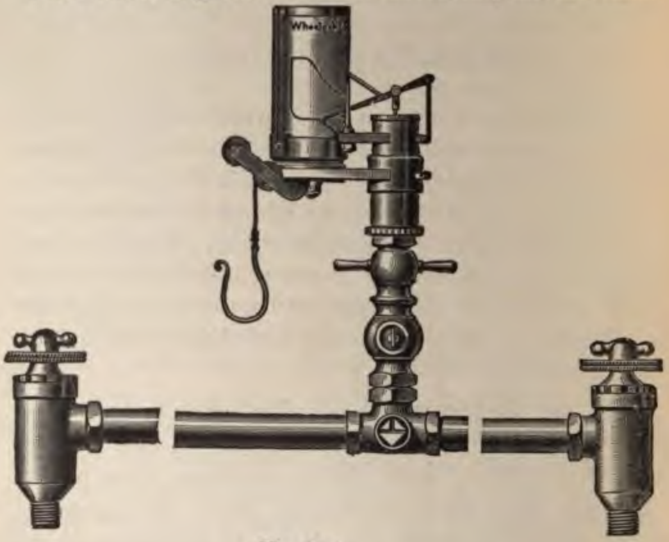
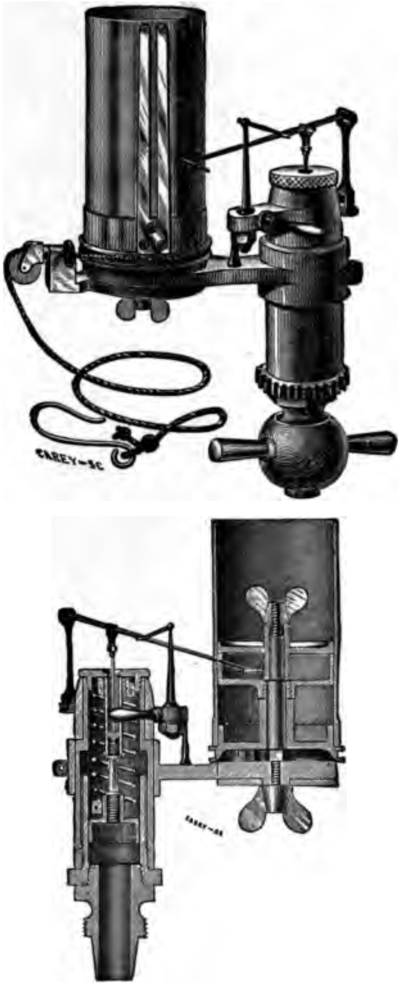


Fig. 118.

An Indicator may be attached to each end of the cylinder n the middle, with a pipe passing to each end of the cylin-



Figs. 119. & 120.

as in *Fig. 118,* but as an indicator of the usual construc-

[illegible] take a diagram or car
[illegible] end of the cylinder a

[illegible]

ay be shut off while a diagram is being taken from the other end, while one end has [illegible] [illegible] [illegible] the indicator is not being used.

In the figure a three (or more) way cock (as it is commonly lled) is shown in place upon the cylinder with a diagram [illegible]

The Thompson Indicator is shown in Fig. [illegible] and a section in Fig. [illegible]

The Tabor Indicator is shown in Fig. [illegible], and a section in Fig. [illegible]

Both are made with the piston and parallel motion as light as possible, in order to enable the taking of diagrams at as ch a speed of engine revolution as possible.

Each Consists of a cylinder and piston, the bottom surface of the latter being in communication with the bore of e engine cylinder, so as to receive whatever steam pressure ere may be in the cylinder.

This Indicator Piston receives on its other surface the essure of a spiral spring which acts to resist the steam essure.

The indicator piston-rod connects to an arm or lever on the end which is a pencil, which by means of a parallel motion caused to move in a straight line.

The Paper or card being in place upon the drum, and am let into the indicator, the pencil lever is moved until e pencil touches the paper as lightly as possible, and as a sult of the combined movements of the pencil and drum e diagram is marked, its form being illustrated in Fig. 3 which represents a diagram placed above a cylinder, and e engine piston in three positions; first, at the beginning the stroke, second, at the point of cut off (which is supposed to be at one third of the stroke), and third, at the point of lease where the valve first opens the port for the exhaust.

tion and such as here referred to, can take a diagram or *card* as it is sometimes called, from but one end of the cylinder at a time, the stop-valves A and B are used, so that the communication between the indicator and one end of the cylinder

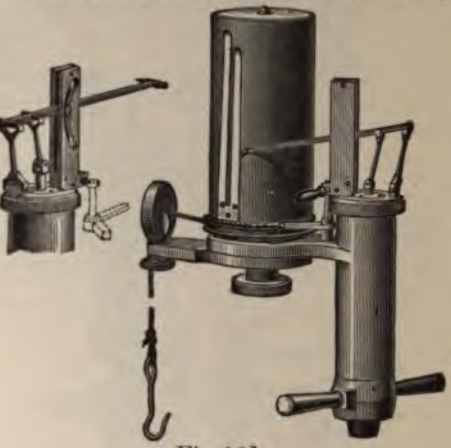


Fig. 121.

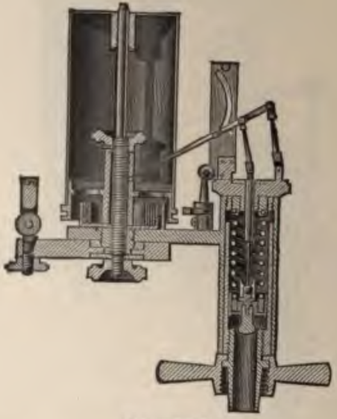


Fig. 122.

may be shut off while a diagram is being taken from the other end, while both ends may be shut off when the indicator is not being used.

In the figure a piece of paper (or card as it is commonly called) is shown in place upon the drum with a diagram upon it.

The Thompson Indicator is shown in Fig. 119, and in section in Fig. 120.

The Tabor Indicator is shown in Fig. 121, and in section in Fig. 122.

Both are made with the piston and paralell motion as light as possible, in order to enable the taking of diagrams at as high a speed of engine revolution as possible.

Each Consists of a cylinder and piston, the bottom surface of the latter being in communication with the bore of the engine cylinder, so as to receive whatever steam pressure there may be in the cylinder.

This Indicator Piston receives, on its other surface, the pressure of a spiral spring, which acts to resist the steam pressure.

The indicator piston-rod actuates an arm or line on the end of which is a pencil, which, by means of a parallel motion, is caused to move in a straight line.

The Paper or *card* being in place upon the drum, and steam let into the indicator, the pencil lever is moved until the pencil touches the paper as lightly as possible, and as a result of the combined movements of the pencil and drum, the diagram is marked, its form being illustrated in Fig. 123 which represents a diagram placed above a cylinder, and the engine piston in three positions; first, at the begining of the stroke, second, at the point of cut-off (which is supposed to be at one third of the stroke), and third, at the point of release where the valve first opens the port for the exhaust.

and that from E to A is the *back pressure line* or *counter pressure line.*

In This Example it has been supposed that while the piston was moving from position 3 to the end of its stroke, and the pencil from D to E, the indicator piston would have a steam pressure on it equal to atmospheric pressure, hence the line from E to A, in this case, represents the atmospheric line, and also the back pressure line.

The Atmospheric Line is a line drawn when there is no steam admitted to the indicator, and represents a pressure above a perfect vacuum equal to the pressure of the atmosphere. Its use is to show the amount of back pressure, and in a condensing engine to show the degree of vacuum obtained.

It also forms a line, wherefrom the line of perfect vacuum, or that of full boiler pressure, may be marked.

The Steam Pressure at any point in the stroke, is denoted by the height of the diagram above the atmospheric line, but the steam pressure thus taken is obviously above atmospheric and is thus the same as the pressure of a steam gauge, which is also above the atmospheric pressure, and therefore represents the pressure that produces useful effect in a non-condensing engine.

This is What May be Called a theoretical diagram, because first, it supposes the steam not to be admitted to the cylinder until the piston was at the end of its stroke, and to attain its full pressure in the cylinder before the piston lead begins to move, whereas, in order to attain a full steam pressure at the beginning of the stroke, the valve must have lead.

Second, it Supposes the cut-off to be effected simultaneously, whereas the valve must have time to move and close the port, and during this time the steam pressure will fall, and the curve C of the diagram will therefore be rounded more or less according to the rapidity with which the valve closed.

Third, it Supposes the steam to have exhausted down to atmospheric pressure by the time the piston had reached the end of the stroke, whereas the piston will have moved some part of the back or return stroke before the steam will have had time to exhaust down to atmospheric pressure, and:

Fourth, it Supposes the steam to remain at atmospheric pressure until the piston arrives at the end of its return stroke, whereas the valve will begin to close the port and cause the steam remaining in the cylinder to compress before the piston has completed its return stroke.

In Practice the diagram will, under favorable conditions, accord nearer to the shape shown in Fig. 124, in which the closure of the port for the cut-off is shown by the curve at F. At the point denoted by *g* the valve began to close, and at the point denoted by *h*, the cut-off was completely effected, and the expanion curve began.

The curve beginning at D is caused by the gradual opening of the exhaust port.

The height of line of back pressure above the atmospheric line shows the amount of back pressure.

At the point *m* where the back pressure line rises into a curve, the valve had closed shutting in the cylinder, a portion of the exhaust steam, which is afterwards compressed by the piston.

This Curve is therefore called the *compession line* or *compression curve.* The point at which it begins cannot be clearly seen when the exhaust port is closed slowly.

The Compression Curve ends at *p* where it merges into the admission line, but the exact point where the compression ends and the admission begins, cannot always be located, this being the case when the port is oponed slowly, or the compression extends through a large portion of the stroke.

The Admission Line is, however, in most cases nearly vertical when the valve has lead, because the valve opens the port quickly while the engine piston is moving at its slowest.

A Diagram as Drawn by the Indicator, Does Not account for all the steam that is used in the cylinder however, as will be seen from Fig. 125, because as the paper drum of the indicator receives its motion from the engine crosshead, its length represents the length of the piston stroke whereas, there is a part of the cylinder bore between the piston (when it is at the end of the stroke), and the cylinder cover, that is filled with steam as is also the steam passage.

This steam performs no useful work during the live steam period, but obviously expands during the expansion period, and therefore affects the expansion curve, and must be taken account of in calculating the consumption of steam, of water, or of coal from the diagram, or in marking in the true expansion curve.

In Calculating the Horse-Power however, it may be neglected, as it does not enter into that subject.

But in Any Calculation involving the amount of steam used, the clearance must be marked in by a line at a right angle to the admission line and distant from the nearest point of the admission line, to an amount that bears the same proportion to the whole length of the diagram, as the clearance does to the whole contents of the cylinder.

The Clearance Line is shown at L L in Fig. 124, its distance from the admission line representing the amount of clearance which includes the contents of the steam port and passage, as well as that of the cylinder bore that is between the cylinder cover and the piston, when the latter is at the end of the stroke.

easuring the amount of clearance was

a Condensing Engine is shown in .responds to Fig. 124 except that the line .um or no pressure is marked in.

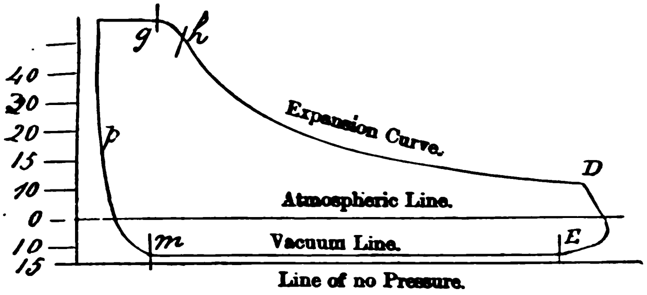


Fig. 125.

It represents a perfect vacuum, and must be marked on all diagrams from which the consumption of steam is to be calculated, because the quantity of steam used obviously includes that which is used in counter-balancing the pressure of the atmosphere.

Learners Often Get Confused on this point, hence it may be more fully explained as follows:

Suppose the engine piston to be blocked in the middle of the cylinder, and has on one side of it a pressure of 20 lbs. of steam by steam gauge, and on the other the pressure of the atmosphere, and we might pump out the steam, thus leaving the cylinder empty on that side of the piston.

The Atmosphere Would Then Exert a pressure of about 14½ lbs. per square inch on one side of the piston, and if we slowly admitted steam again, it would have to get up a pressure of 14½ lbs. per square inch before the atmospheric pressure would be counter-balanced and the piston be in equilibrium.

But the steam gauge would at this time stand at zero, and not show that there was any steam in the cylinder, because the zero of the steam gauge is atmospheric pressure.

When, Therefore, the Steam Gauge showed a pressure of 20 lbs. of steam, in the cylinder, there would actually be a pressure of 34½ lbs. of steam per square inch.

The Clearance Line and the Vacuum Line must Both, therefore, be marked on the diagram when the quantity of steam used is to be computed from the diagram, and also when the proper or theoretical expansion curve is to be marked on the diagram.

This is Clear, Because in finding the expansion curve for a given volume of steam, the whole of its volume must be taken into account, and this whole volume is represented by the area enclosed within the clearance line, the steam line, the expansion curve, the exhaust line, and the line of perfect vacuum, or line of no pressure.

The Atmospheric Line Should be Drawn after the diagram has been taken, and while the indicator is hot, as the expansion of the indicator affects the position of this line. It is drawn with the steam shut entirely off from the indicator, whose piston therefore has atmospheric pressure on both sides of it.

Whether the Engine is condensing or non-condensing, the same amount of steam (all other things being equal) is used, the only difference being that in a condensing engine a greater portion of the steam is available for driving the piston.

If the Condenser Produced a Perfect Vacuum, the whole of the steam would be utilized in propelling the piston.

The "Line of no Pressure" or of perfect vacuum, is marked as far below the atmospheric line as will represent the pressure of the atmosphere, which is, at the sea level, about 14.7 lbs. per square inch when the barometer stands at 29.99 inches.

THE BAROMETER

A Barometer is an instrument for denoting the pressure or weight of the atmosphere, which it does by means of a column of mercury enclosed in a tube, in which there is a vacuum which may be produced as follows:

A tube having a parallel bore and closed at one end is filled with mercury, and while the finger is placed over the open end of the tube it is turned upside down and inverted in a cup of mercury that is open to receive the pressure of the atmosphere.

The Finger is then removed from the end of the tube and the mercury will fall, leaving a vacuum at its upper end

The pressure of the atmosphere on the surface of the mercury in the cup forces the mercury up the tube, because the surface of the mercury in the tube has no atmospheric pressure on it, the action being the same as that already described, with reference to the principles of action of a pump.

The weight of the atmosphere is equal to the weight of that part of the column of mercury hat is above the surface of the mercury in the cup, hence lines may be drawn at different heights representing the weight of the atmosphere, or of any other gas when the column of mercury stands at the heights denoted by the respective lines.

But as Mercury Expands by Heat, a definite degree of temperature must be taken in marking a column, to represent the weight, this temperature being 32 degrees Fahrenheit.

Similarly, as the Weight of the Atmosphere varies, according to the height at which it is taken from the surface of the earth, a definite height must be taken.

The sea level is that usually taken, the mean or average atmosphere (at that level), being 14.7 lbs. per square inch.

For higher altitudes, the mean atmospheric pressure in lbs. per square inch, may be found by multiplying the altitude or height above sea level by .00053, and subtracting the product from 14.7

Each Pound on the Square Inch is represented by a height of 2.036 inches of mercury, hence the height of a column of mercury at a temperature of 32° that will balance the mean weight of the atmosphere is 29.92 inches, and to avoid fractions, it is usual (for purposes not requiring to be very exact) to say that the atmospheric pressure at sea level is represented by 30 inches of mercury.

The Atmospheric Pressure is also to avoid using fractions taken roughly at 15 lbs. per square inch at sea level.

Each Two inches of Mercury will, under these conditions, represent 1 lb. of pressure.

Vacuum Gauges are based upon the same principles and subject to the same variations as to altitude, as mercury gauges or the barometer.

To Find the absolute pressure, or pressure above zero or a perfect vacuum, we may add the pressure of the boiler steam gauge to that shown by the mercury gauge or barometer.

In Fig. 125 the line of no pressure is marked at 15 lbs. per square inch below the vacuum line of the diagram, the atmospheric pressure being for convenience taken as 15 lbs. above a perfect vacuum.

The Line of no pressure serves as a guide in showing the effectiveness of the condenser, as well as for computing the volume of steam used, but is not necessary in computing the horse-power of a non-condensing engine, because the gauge pressure has its zero marked to correspond with the atmospheric pressure.

In Computing the Consumption of steam or Water from the diagram, therefore, both the clearance line and the line of no pressure must be marked on the diagram, and lines of the diagram extended so as to include them, thus accounting for all the steam that leaves the steam-chest from the piston-stroke.

Indicator Springs are varied in strength to suit the pressure of steam they are to be used for.

The Scale of the spring is the number of lbs. pressure per square inch represented by a vertical motion of the pencil, thus a 40 lb. spring is one in which a pressure of steam of 40 lbs. per square inch would cause the piston to rise an inch above the atmospheric line of the diagram.

The strength, or tension, of the spring is so adjusted as to cause the diagram to be about 2½ inches high, let the steam pressure be what it may. The following are the scales of springs of the Thompson and Tabor indicator.

A Spring That is Strong Enough for a given pressure may be used for any less pressure.

The Height of the Diagram will, however, be less, and accuracy is best secured by having the diagram up to the limit of about 2½ inches, using a spring that is light enough to secure this result.

Diagrams of High Speed Engines however, will have their lines more regular in proportion, as a bearer spring is used.

This Occurs Because the spring being under more tension is less liable to vibration.

.An Indicator Requires careful cleaning, and oiling with the best of oil, as the slighest undue friction seriously impairs the working of the instrument.

THOMPSON INDICATOR.

Scale of spring	Used for pressure above atmosphere if not more than
15 lbs.	21 lbs. per square inch.
20 “	38 “ “ “ “
30 “	94 “ “ “ “
40 “	90 “ “ “ “
60 “	143 “ “ “ “

TABOR INDICATOR.

10 “	14 “ “ “ “
12 “	20 “ “ “ “
16 “	30 “ “ “ “
20 “	40 “ “ “ “
24 “	48 “ “ “ “
30 “	60 “ “ “ “
32 “	64 “ “ “ “
40 “	80 “ “ “ “
48 “	96 “ “ “ “
50 “	100 “ “ “ “
60 “	120 “ “ “ “
64 “	128 “ “ “ “
80 “	160 “ “ “ “

Instructions Upon the care of the instrument, and how to take it apart, etc., are usually given by the makers of the indicator.

There are Various Methods of giving to the paper drum of the indicator a motion coincident with that of the engine piston, but few of them give correct results.

Reducing Levers, such as shown in Fig. 126, are constructed as follows:

Fig. 126 represents a reducing lever with the indicators attached, A C is a strip of pine board three or four inches wide and about one and one-half times as long as the stroke of the engine. It is hung by a screw or small bolt to a wooden frame attached overhead. A link C ⅓ as long as the stroke, is attached at one end to the lever, and at the other end to a stud screwed into the cross-head, or to an iron clamped to the cross-head by one of the nuts that adjust the gibs, or to any

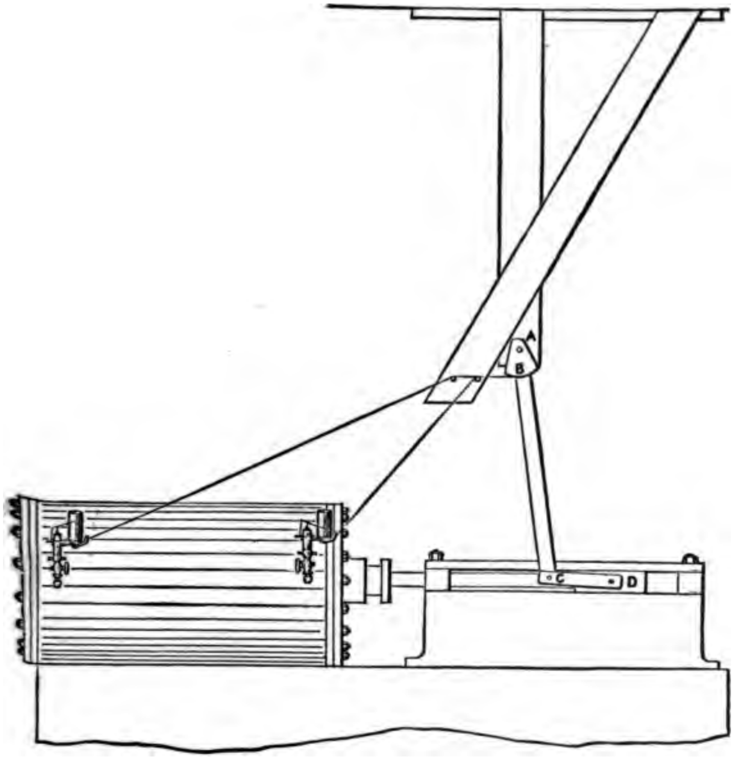


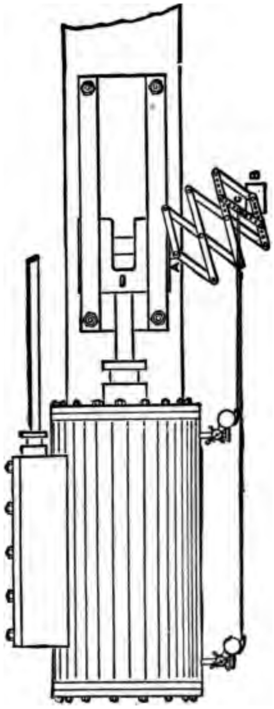
Fig. 126.

part of the cross-head that may be conveniently used. The lever should stand in a vertical position when the piston is [illegible] the middle of the stroke. The connecting-rod, when [illegible] that point, should be as far below a horizontal position [illegible] it is above it at either end of the stroke. The cords which drive the paper drums may be attached to a screw inserted in the lever near the point of suspension, but a better plan is to provide a segment, A B, the center of which coincides with the point of suspension, and allow the cord to pass around the circular edge. The distance from edge to center should bear the same proportion to the length of the reducing lever as the desired length of diagram bears to the length of the stroke. On an engine having a stroke of 48 inches, the lever should be 72 inches, and the link C 16 inches in length, in which case, to obtain a diagram 4 inches long, the radius of the segment would be 6 inches. It is immaterial what the actual length of the diagram is, except as it suits the operators fancy, but 4 inches is a length that is usually satisfactory. It may be reduced to advantage to 3 inches at very high speeds. The cords should leave the segment in a line parallel with the axis of the engine cylinder.

The pulleys over which they pass should incline from a vertical plane and point to the indicators wherever they may be located. If the indicators and the reducing lever can be placed so as to be in line with each other, the pulleys may be dispensed with, and the cords carried directly from the segment to the instruments, a longer arc being provided for this purpose. The arm which holds the carrier pulleys on each indicator should be adjusted so as to point in the direction in which the cord is received

In All Arrangements of this kind the reduced motion is not mathematically exact, because the leverage is not constant at all points of the stroke.

Pantagraph Motions have been devised for overcoming these defects. Two forms have been successfully used, which if well made, well cared for, and properly handled, reproduce the motion on the reduced scale with perfect accuracy. They are shown in working position in Figs. 127 and 128.



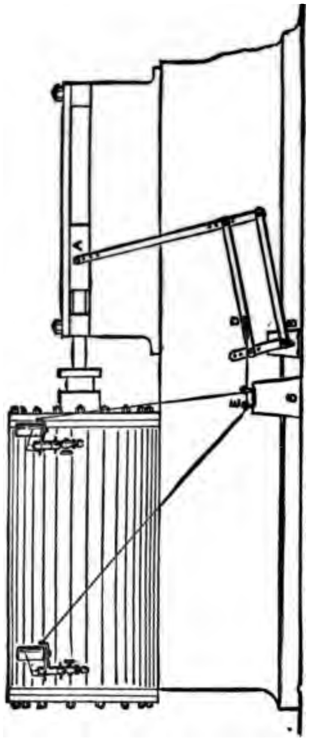
Application of the Pantagraph when the Indicator is on the Side of the Engine Cylinder.

Fig. 127.

Fig. 127 represents the manner of attaching the pantagraph motion or *lazy tongs*, as it is sometimes called, when the indicators are applied to the side of the cylinder. It works in a horizontal plane, the pivot end being supported by a post B erected in front of the guides, and the working end receiving motion from an iron attached to the cross-head.

By Adjusting the Post to the proper height and at a proper distance in front of the cross-head, the cords may be carried from the cord pin C to the indicators, without the intervention of carrier pulleys.

If the Indicators are Attached to the side of the cylinder the simplest form of pantagraph shown in Fig. 128 may be used. The working end A receives motion from the cross-head, and the front piece B is attached to the floor. The cord pin D is fixed in line between the pivot and the work-



A Simple Indicator Rigging.

Fig. 128.

ing end, and the pulleys E, attached to the block C, guide the cords to the indicators.

The Indicator Rigging that gives the best results at high speeds is a plain reducing lever like that first described, provided at the lower end with a slot that receives a stud, screwed into the cross-head. The length of the lever should be two and one-half times the engine stroke.

Whatever Plan is Followed, it is desirable to avoid the use of long stretches of cord. If the motion must be carried a long distance, strips of wood may often be arranged in their place and operated with direct connections. Braided linen cord, a little in excess of one-sixteenth of an inch in diameter, is a suitable material for indicator work.

To Take a Diagram a blank card is stretched smoothly upon the paper drum, the ends being held by the spring clips. The driving cord is attached and so adjusted that the motion of the drum is central.

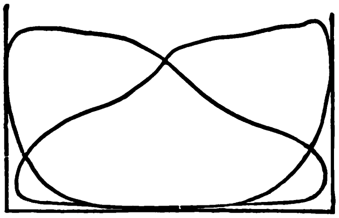


Fig. 129.

For convenience the two diagrams may be made on the same card, as shown in Fig. 128.

TESTING THE EXPANSION CURVE.

The Usual manner of testing the expansion curve of a diagram, is to compare it with a curve representing Marriott's law for the expansion of a perfect gas.

A Theoretic Expansion curve that will accord with Marriott's law, may be constructed on the diagram by the following method:

The Diagram, as Drawn by the Indicator, will have the atmospheric line upon it, and from this as a basis, we may mark in the line of no pressure or line of perfect vacuum.

To do this we draw, beneath the atmospheric line, a line as far beneath it as will represent the atmospheric line, on the same scale as the spring used, in the indicator, to draw the diagram.

Suppose, for example, that a 30 lb. spring was used, and assuming the atmospheric pressure to be 15 lbs. per inch, then the line of no pressure would be drawn half an inch below the atmospheric line, because 15 lbs. pull on the spring would cause it to distend half an inch.

The Clearance Line Must Then be Drawn in according to directions that have already been given.

The Next Thing to do is to divide the length of the diagram into any convenient number of equal parts, by vertical lines parallel to, and beginning at, the clearance line, as shown in Fig. 130. These lines are numbered as shown, ten of them being used because that is a convenient number, but any other number would do.

We Next Decide at which part of the diagram its expansion curve and the test curve shall touch, and in this example we have chosen that it shall be at line 10.

We Have Now to Find what pressure the length of line 10 represents on the scale of the indicator spring, which in this case we will suppose to be 25 lbs., the line measuring $\frac{25}{30}$ of an inch, and a thirty pound spring having been used to draw the diagram. Next multiply the pressure (25 lbs.) by the number of the line (10), and divide the product (250) by the number of each of the other lines in succession, and the quotient will be the pressures to be represented by the lines.

For Example, For Line 9 we have that 250 divided by 9 gives 27.7, hence line 9 must be long or high enough to represent a pressure of 27.7 lbs. above a perfect vacuum, or in this case $\frac{27.7}{30}$ of an inch.

For line 8 we have that 250 divided by 8 gives 31.25 lbs., hence line 8 must be high enough to represent a pressure of 31.25 lbs. above a perfect vacuum.

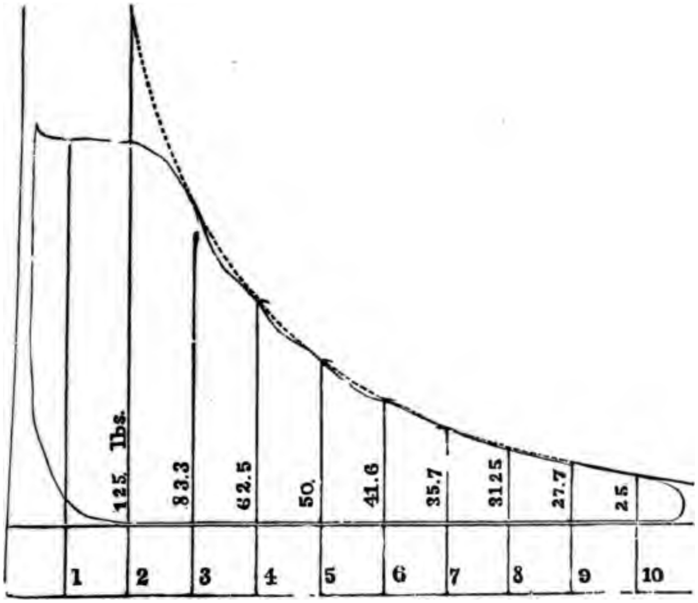


Fig. 130.

The Atmospheric Line is, in this case, of no other service than to form a guide wherefrom to mark in the line of no pressure, or of perfect vacuum.

Now Take the Case of line 5, and 250 divided by 5 gives [illegible] hence the height of line 7 must represent a pressure above vacuum of [illegible] pounds.

Having Carried This Out for all the lines from line 10 to line [illegible], we draw in the true expansion curve, which will touch the tops of all the lines.

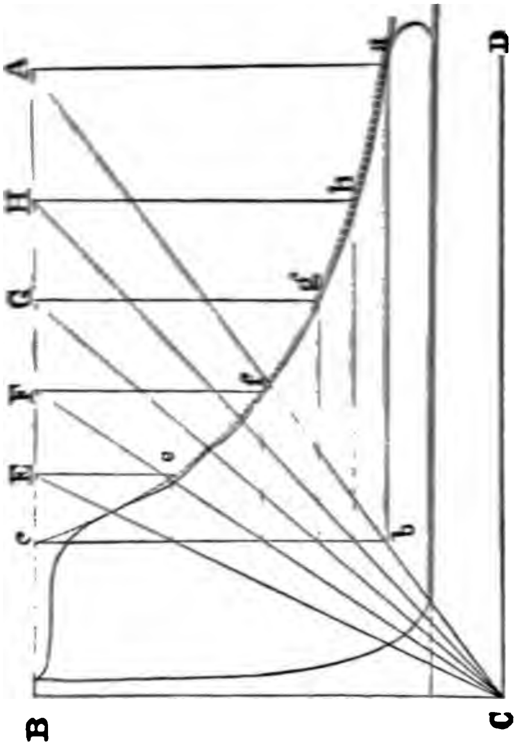


Fig. 131.

Another Method of drawing this curve is shown in Fi 131. Having drawn the clearance and vacuum lines as b fore and chosen where the curves shall touch (as at *a*), th draw from *a* a perdendicular *a* A.

Draw line A B parallel to the vacuum line, and at any convenient height above or near the top of the diagram.

From A draw A C, and from *a* draw *a b* parallel to D C, then from its intersection with A C, erect the perpendicular *b c*, locating, on A B, the theoretical point (*c*) of cut-off.

From a Number of Points on A B (which may be located without regard to equally spacing them), such as E F G and H, draw lines to C, and also drop pendicular lines, as, E *e*, F *f*, G*g*, H *h*.

From the Intersection of E C with *b e* draw a horizontal line to *e*. From the intersection of F *c* with *b c* draw a horizontal line, and so on; and where these horizontals cut the verticals (as at *c f g h*) are points in the curve, which begins at *c* and passes through *e f g h*, to *a*.

But this curve does not correctly represent the expansion of steam. It would do so if the steam remained, or was maintained at a uniform temperature; hence it is called the isothermal curve, or curve of same temperature. But in fact steam and all other elastic fluids fall in temperature during their expansion, and rise during compression, and this change of temperature slightly affects the pressure.

A Curve in which the combined effects of volumn and resulting temperatures is represented, is called the *adiabatic* curve, or curve of no transmission; since, if no heat is transmitted to or from the fluid during change of volume, its sensible temperature will change according to a fixed ratio, which will be the same for the same fluid in all cases.

A Sufficiently Close approximation to the adiabatic curve to enable the non-professional engineer to form an idea of the difference between the two, may be produced by the following process:

Taking a similar diagram to that used for the foregoing illustrations, we fix on a point A near the terminal, where the total pressure is 25 pounds. As before, this point is chosen in order that the two curves may coincide there, as in Fig. 132.

Any other Point might have been chosen for the point

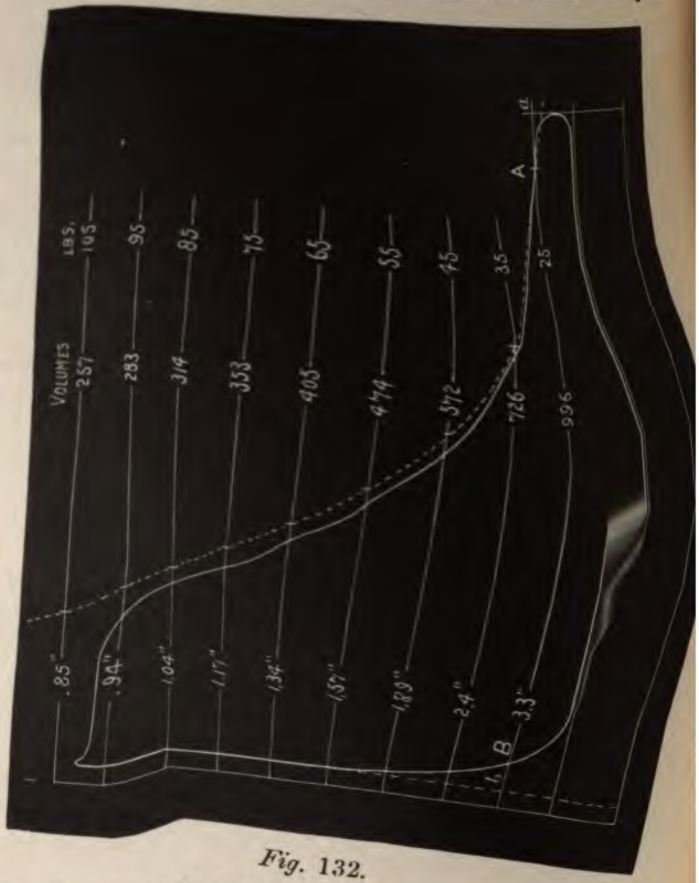


Fig. 132.

of coincidence; but a point in that vicinity is generally chosen, so that the result will show the amount of power that should be obtained from the existing terminal. This point is 3.3 inches from the clearance line, and the volume of 25 pounds 996, that is, steam of that pressure has 996 times the bulk of water.

Now if we Divide the distance of A from the clearance line by 996, and multiply the quotient by each of the volumes of the other pressures indicated by similar lines, the products will be the respective lengths of the lines measured from the clearance line; the desired curve passing through their other ends. Thus, the quotient of the first or 25-pound pressure line divided by 996 is .003313; this multiplied by 726, the volume of 35 pounds pressure, gives 2.4, the length of the 35-pound-pressure line; and so on for all the rest.

The Application of either of the above curves will show that some diagrams are much more accurate than others, even though taken from engines of the same design and quality ot workmanship.

As a general Rule those from large engines will be more correct than from small ones, and those from high more correct than from low speeds, and in either case efficiently covering the steam pipes and jacketting the cylinder, to prevent condensation, will improve the diagram.

The Character of the imperfection in the expansion curve, shown by the application of a test curve, is generally too high a terminal pressure for the point of cut-off, the first part of the curve being generally the most correct, and nearly all the inaccuracy appearing in the last half.

The Usual Explanation of this is that the steam admitted during the live steam period condenses because of having to heat the cylinder, and that this water of condensation re-evaporates during the latter part of the stroke when this water of condensation is at a higher temperature than the expanded steam, and thus increases the pressure.

A Leaky admission valve may generally, however, be looked for (or else wet steam), if the expansion curve rises much during its lower half.

TO CALCULATE THE HORSE-POWER FROM A DIAGRAM.

In Calculating the Horse-Power of an engine, the only assistance given by the indicator, is that it provides a means of obtaining the average pressure of the steam throughout the piston-stroke.

There are two methods of doing this, one by means of a planimeter or averaging instrument, and the other by means of lines called *ordinates.*

The Ordinates or lines are drawn at a right angle to the atmospheric line, as shown in Fig. 133, and each line is taken to represent the average height or length of one-half of the space between itself and the next lines.

Suppose, for example, that we require to get the area of that part of the diagram that lies between the dotted lines in the figure, and it is clear that the average height of this part of the diagram is represented by the height of the full line between them.

Any Number of Ordinates may be used and the greater their number the greater the accuracy obtained. It is, however, usual to draw 10.

The end ordinates A and D, in the figure, should be only half the distance from the ends of the diagram that they are from the next ordinate, as will be seen when it is considered that the ordinate is in the middle of the space it represents.

The Ordinate Being Drawn their lengths are added together, and the sum so obtained is divided by the number of ordinates, which gives the average height of the ordinates.

Suppose then, that the average height of the ordinate is two inches, and that the scale of the spring of the indicator that took the diagram was 30 lbs. then the average pressure,

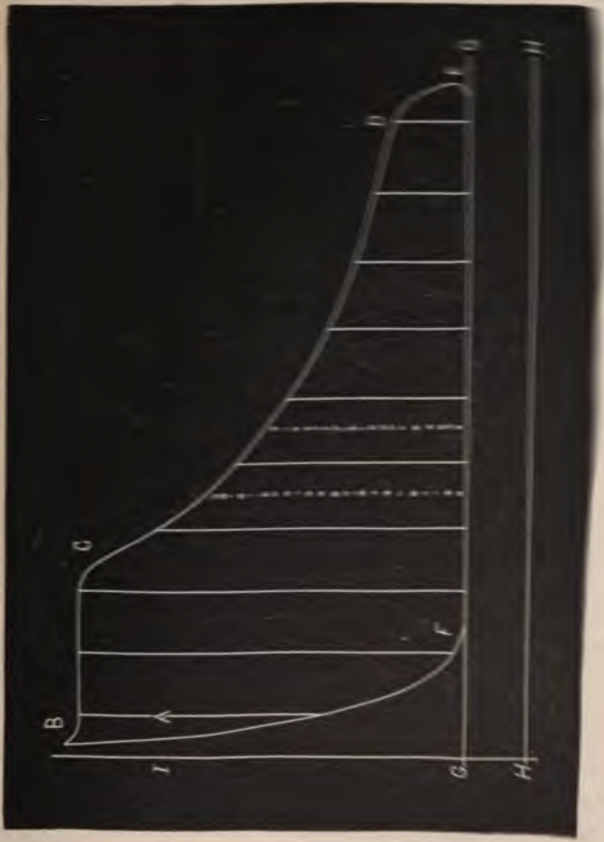


Fig. 133.

hown by the diagram, will be 60 lbs. per square inch. Or n other words, each inch in the height of the ordinate repreents 30 lbs. pressure per square inch.

The Mean Effective Pressure having been found, the indicated horse-power (or I. H. P. as it is given in brief) is found by multiplying together the area of the piston (minus half the area of the piston-rod when great accuracy is required) and the travel of the piston in feet per minute, and dividing the product by 33000 an example having been given on pages from 283 to 285.

It is to be Observed however that when great accuracy is required a diagram should be taken from each end of the cylinder, as the mean effective pressure at one end of the cylinder may vary considerably from that at the other.

This will be the Case when a single valve is used with equal lap, because, in this case, the point of cut-off will vary on one stroke as compared with the other, which occurs by reason of the angularity of the connecting-rod.

When Cut-off Valves or two admission valves are used, it may occur from improper adjustment of the valves. It occurs in all engines, because on one side of the piston the piston-rod excludes the steam from the piston face, unless indeed, the piston-rod passes through both covers, in which case the rod area must be subtracted from the piston area.

If the Expansion Curve in a diagram from a non-condensing engine should pass below the atmospheric line, then the mean effective pressure of that part of the card that is below the atmospheric line, must be subtracted from the mean effective pressure of that part that is above the atmospheric line, because the part below represents back pressure or pressure resisting the piston motion.

The Planimeter Affords a much quicker, and more accurate method of obtaining the average steam pressure from a diagram.

Coffins Averaging Instrument or planimeter is shown in Fig. 134, and the method of using it is as follows:

A quick method of approximating the mean effective pressure (or M. E. P. as it is called) of a diagram is to draw a line *a b*, in Fig. 135, touching the expansion curve at *a*, and

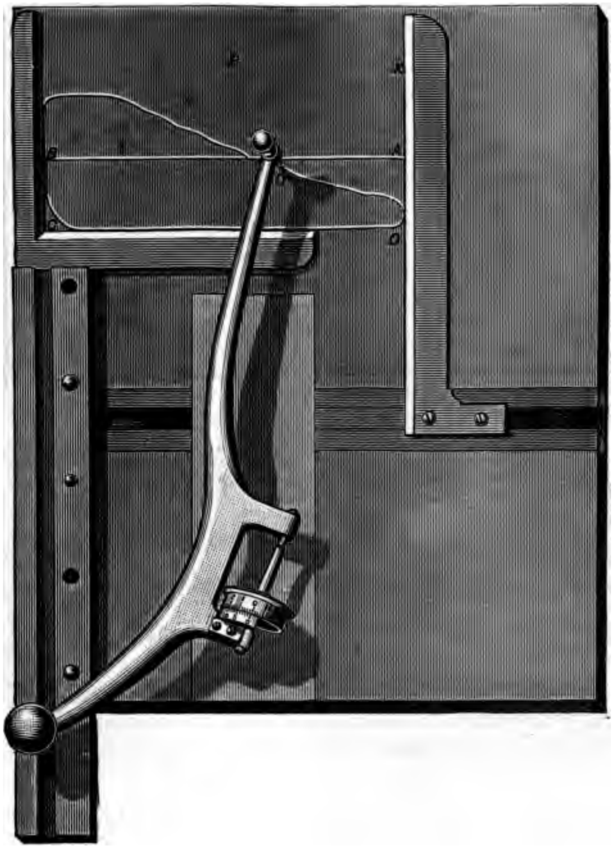


Fig. 134.

so inclined that the space *e* is, as near as the eye can judge, equal to the space *d.* Then the line *f* draw in the middle of the diagram, and, measured on the scale of the spring

that was used to take the diagram, represents the mean effective pressure, or M. E. P., of the diagram.

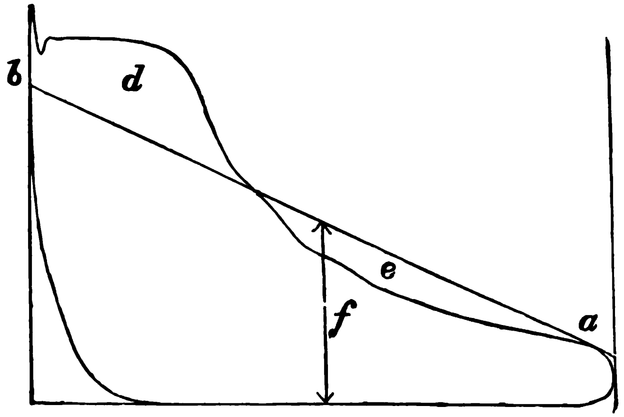


Fig. 135.

CALCULATING THE AMOUNT OF STEAM OR WATER USED.

The Amount of Water evaporated in the boiler is not accounted for by an indicator diagram or card, and the full reasons for this are not known.

It is obvious, however, that the loss, from the steam being unduly wet or containing water held in suspension, is not shown by the diagram, and this amount of loss will vary with the conditions.

Thus the Loss from this cause will be less in proportion as the point of cut-off occurs earlier in the stroke, because as the water is at the same temperature as the steam, it will, as the temperature of the steam reduces from the expansion, evaporate more during the expansion period, doing so to a greater extent in proportion as the cut-off is early, on account of there being a wider variation between the temperature of the steam at the point of cut-off and at the end of the stroke. On the other hand, however, in proportion as the cut-off is earlier, the proportionate loss from condensation during the live steam period, is greater, because a greater length of the cylinder-bore is cooled during the expansion period, and it has more time to cool in.

Whatever Steam is Saved by the Compression, from the exhaust, must be credited to the engine in calculating the water consumption from the indicator card or diagram since it fills, or partly fills the clearance space.

In engines which vary the point of cut-off, by varying the travel of the induction or admission valve, the amount of compression is variable with the point of cut-off, and increases in proportion as the live steam period diminishes; hence to find the actual water or steam consumption per horse power per hour, diagrams would require to be taken continuously from both ends of the cylinder during the hour; assuming, however, that the point of cut-off remains the same, that the amount of compressson is constant, that the steam is saturated, and neither wet nor superheated, steam and the water consumption may be computed from the diagram as follows:

Water-consumption Calculations. An engine driven by water instead of steam, at a pressure of one pound per square inch, would require 859,375 pounds per horse power per hour; the water being of such temperature and density that one cubic foot would weigh 62½ pounds. If the mean pressure were more than one pound, the consumption would be proportionately less; and, if steam were used, the consumption would be as much less as the volume of steam used was greater than an equal weight of water. Hence, if we divide the number 859,375 by the mean effective pressure and by the volume of the termal pressure, the result will be the theoretical rate of water consumption in pounds per I. H. P. per hour.

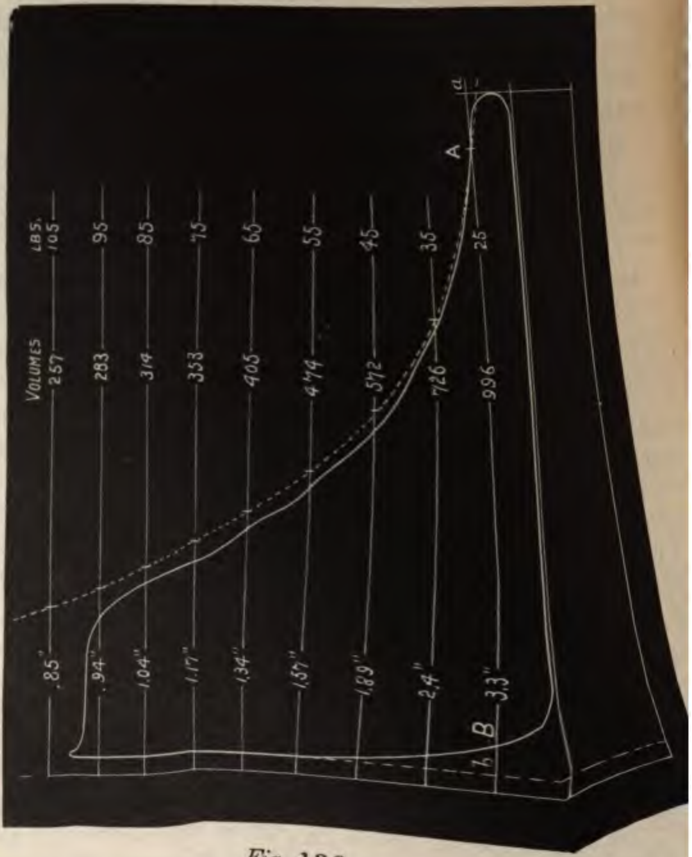


Fig. 136.

For the terminal pressure, we may take the any convenient point in the expansion curve near al, as at A, Fig. 136, in which case the result fou diminished in the proportion that the portion remaining to be made, A *a* bears to the whole length of the stroke *a b*; and it may also be diminished by the proportion of stroke remaining to be made after the pressure at A has been reached in the compression curve at B. In other words, A B is the portion of the stroke *a b* during which steam at the pressure at A is being consumed. Hence the result obtained by the above rule is multiplied by A B, and the product divided by *a b*.

To Illustrate, suppose the mean effective pressure of the diagram to be 37.6 pounds, and the pressure at A 25 pounds, of which the volume is 996. Then $\frac{859,375}{37.6\times996} = 22.94$ pounds water per I. H. P. per hour, the rate that would be due to using an entire cylinder full of steam at 25 pounds pressure every stroke. But as the period of consumption is represented by B A, *b a* being the stroke, the following correction is required:

$\frac{22.94\times3.03}{3.45''} = 20.15$; 3,03 inches being the portion B A, and inches being the whole length *b a*. This correction allows for the effects of clearance as well as compression, since, if more clearance had existed, the pressure at A would not have been reached till later in the stroke, and the consumption line B A would have been longer.

But such a rate can never be realized in practice. Under the best attainable conditions, such as about the load indicated on the diagram, or more on a large engine with steam-tight valves and piston, and well protected cylinder and pipes, the unindicated loss will seldom be less than 10 per cent, and it will be increased by departure from any of the above conditions to almost any extent. It will increase at an accelerating ratio as the load is diminished, so that such calculations applied to light-load diagrams would be deceptive and misleading; in fact they have but little practical value, except when made for comparison with tests of actual consumption for the purpose of determining the amount of loss under certain given conditions.

DEFECTIVE DIAGRAMS.

In Seeking the causes that may produce a defective diagram, the following points should be remembered.

The Indicator Must be kept in perfect order, thoroughly clean and well lubricated, so that its parts will move freely. It should always be cleaned throughout after using.

The Motion of the Indicator Drum should be an exact copy, on a reduced scale, of that of the piston at every point in the stroke.

The Steam Pipes from the cylinder to the indicator, if any are used, must be large enough to give a free and full pressure of steam, and care must be taken that the water of condensation does not obstruct them or enter the indicator.

The Cord should be as strong as possible, or if long, fine wire should be substituted.

The Pencil should be held to the card with just sufficient force to make a fine line with a sharp pencil.

The Diagram Should be as Long as the Atmospheric Line, any difference in this respect showing unequal tension of the cord, probably from unequal pressure of the pencil to the paper or card.

A Fall in the Steam Line could arise from too small a steam pipe, and this could be tested by a diagram taken from the steam-chest. It could also occur from too small a steam port or an obstructed steam passage as well as from a leaky piston.

.n expansion curve that is higher than it should be, may e from a leaky valve letting in steam after the cut-off had urred, or if at the later point of expansion curve, it may caused by the steam being wet or containing water,

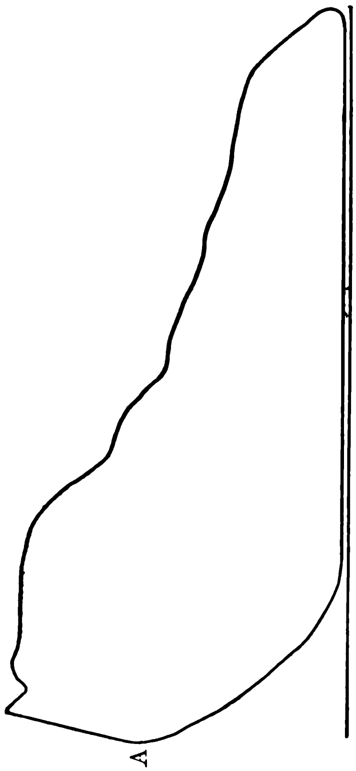


Fig. 137.

ch evaporates as the temperature falls from the expan-
.

n Expansion Curve that is Lower Than it Should may be caused by a leaky piston, by a valve that leaks on the exhaust side but not on the steam side, or if the exhaust valve is separate from the steam valve, it may leak while the steam valve is tight.

It may also be caused by the cylinder being unduly cooled, as from water accumulating in a steam jacket.

There are Many Defects in the adjustment of the valve gear. or of improper proportion in the parts that may be clearly shown by a diagram, while there are defects which might exist and that would not be shown on the diagram.

It is possible, for example, that a steam valve and the engine piston may both leak to the same amount, and as a result the expansion curve may appear correct and not show the leak.

Insufficient valve lead would be shown by the piston moving a certain portion of its stroke before the steam line attained its greatest height in Fig. 137, in which from A upwards, the admisson line instead of rising vertically, is at an angle to the right, showing that the piston had moved a certain portion of its stroke before full pressure of steam was admitted.

That Too Small a Steam Port or Steam Pipe Did Not cause this defect, may be known from the following reasoning.

The Port Opened when the pencil was at A, which shows that the valve had lead. At this time the piston was near the dead center and moving slower than it was when the pressure reached its highest point on the diagram, and since the steam line is fairly parallel with the atmospheric line, it shows that the port was large enough to maintain the pressure when the piston was travelling fast, and therefore ample when the piston was moving slow.

The Remedy in this case, is to set the eccentric back.

With Less Compression the point A would be lower.

Excessive Lead is shown in Fig. 138 by the loop at A, where the compression curve extends up to the steam line, and the lead carries the admission line above it, because of the piston moving against the incoming steam.

To mark in the theoretical compression curve, the vacuum line and the clearance line must be drawn in as in the figure, and ordinates must be drawn.

According to the diagram, in Fig. 138, the compression is clearly defined to have begun at C, and at that time the space

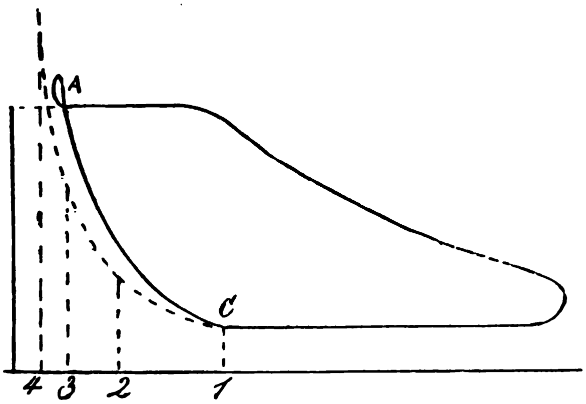


Fig. 138.

filled by steam is represented by the distance from C to the clearance line. The pressure above vacuum (or total pressure), of the steam in the cylinder when the compression began is represented by the length or heighth of the dotted line 1.

Now suppose the piston to have moved from the point C where compression began, to line 2 (which is midway between line 1 and the clearance line), and as the compressed steam occupies one-half the space it did when the piston was

on the exhaust side but not on th
haust valve is separate from t
while the steam valve is tight.
It may also be caused by t
as from water accumulating

There are Many Def
gear, or of improper
clearly shown by a d
might exist and that
It is possible, fo
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gh as line 1.
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be marked midway between
and twice as high as line 2, be-
ll occupy half the space it did at
r midway between line 3 and the
these lines we may draw the theo-
e, which is shown dotted in.

ount of Steam actually saved by the
e to consider the compression curve
e point of the diagram where it is con-
compression actually began, and ending
ssion line joins the admission line, and the
e between these two points, represents the
nder-bore filled by the compression.

e average amount to which the steam is com-
ust draw within this length of the diagram,
e boundaries of the compression curve and the
ressure ordinates, corresponds to those given for
average shown pressure of a diagram, as explain-
erence to that subject, taking care to have the end
paced half as wide as the intermediate ones, as ex-
th reference to Fig. 133.

EXAMPLES OF DIAGRAMS.

s of Diagrams from Locomotives are given
ures from 139 to 164, which were taken from engine
22, of the Philadelphia and Reading railroad. The
of the engine are as follows:

's Link Motion, Cylinders 18½-inch bore,

[illegible]

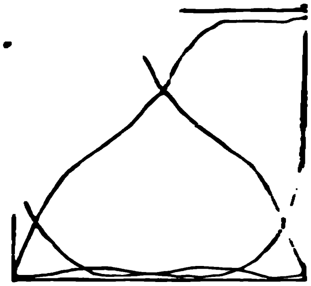

Fig. 139.

Steam pressure on boiler, lbs.	135.
Throttle	wide open
Revolutions per minute	88
Cutting off steam at, in.	9
Area of exhaust nozzle, in.	19 6-10

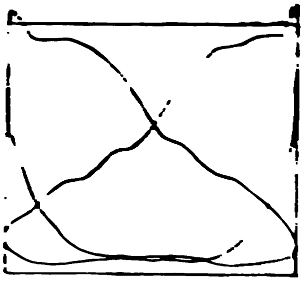

Fig. 140.

Steam pressure on boiler, lbs.	125
Throttle	wide open
Revolutions per minute	198
Cutting off steam at, in.	8
Area of exhaust nozzle, in.	19 6.10

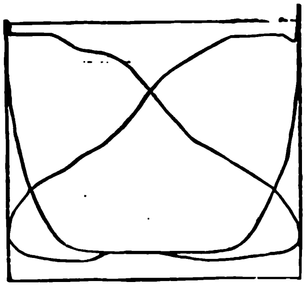

Fig. 141.

Steam pressure on boiler, lbs.	130
Throttle	wide open
Revolutions per minute	260
Cutting off steam at, in.	10
Area of exhaust nozzle, in.	19 6-10

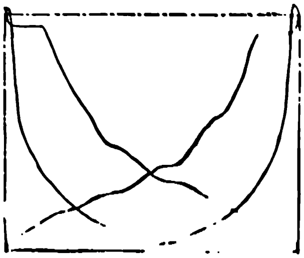

Fig. 142.

Steam pressure on boiler, lbs.	120
Throttle	wide open
Revolutions per minute	171
Cutting off steam at, in.	4
Area of exhaust nozzle, in.	19 6 10

at C, therefore the steam pressure will be doubled, and line 2 may be drawn making it twice as high as line 1.

Line 2 is Now the Starting Point for getting the next ordinate, line 3, and must be marked midway between line 2 and the clearance line, and twice as high as line 2, because at line 3 the steam will occupy half the space it did at line 2. Line 4 is obviously midway between line 3 and the clearance line.

Through the Tops of these lines we may draw the theoretical compression curve, which is shown dotted in.

To Find the Amount of Steam actually saved by the compression, we have to consider the compression curve only, beginning at the point of the diagram where it is considered that the compression actually began, and ending where the compression line joins the admission line, and the horizontal distance between these two points, represents the length of the cylinder-bore filled by the compression.

To Find the average amount to which the steam is compressed, we must draw within this length of the diagram, and within the boundaries of the compression curve and the line of no pressure ordinates, corresponds to those given for finding the average shown pressure of a diagram, as explained with reference to that subject, taking care to have the end ordinates spaced half as wide as the intermediate ones, as explained with reference to Fig. 133.

EXAMPLES OF DIAGRAMS.

Examples of Diagrams from Locomotives are given in the figures from 139 to 164, which were taken from engine number 222, of the Philadelphia and Reading railroad. The dimensions of the engine are as follows:

Stephenson's Link Motion, Cylinders 18¼-inch bore, 22-inch stroke; four driving wheels, 67½-inch diameter; total heating surface, 1089 square feet; weight on driving wheels, 60,780 pounds; total weight of engine 89,750 pounds.

The conditions under which each diagram was taken are stated beneath it.

The scale of the indicator spring was 90 lbs. per inch, or in other words, each inch in the height of the diagram above the atmospheric line indicates 90 lbs. pressure per square inch.

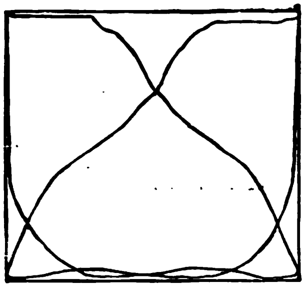

Fig. 139.

Steam pressure on boiler, lbs.	135.
Throttle	wide open
Revolutions per minute	88
Cutting off steam at, in.	9
Area of exhaust nozzle, in.	19 6-10

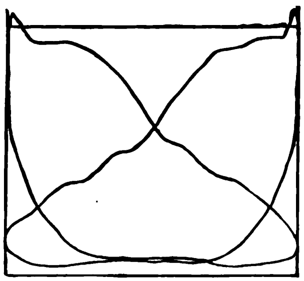

Fig. 140.

Steam pressure on boiler, lbs.	125
Throttle	wide open
Revolutions per minute	198
Cutting off steam at, in.	8
Area of exhaust nozzle, in.	19 6,10

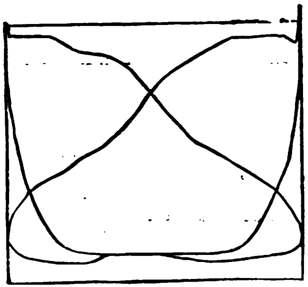

Fig. 141.

Steam pressure on boiler, lbs.	130
Throttle	wide open
Revolutions per minute	260
Cutting off steam at, in.	10
Area of exhaust nozzle, in.	19 6-10

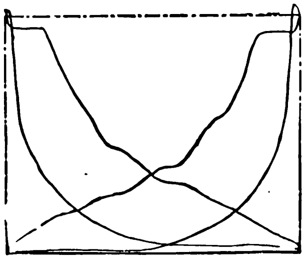

Fig. 142.

Steam pressure on boiler, lbs.	120
Throttle	wide open
Revolutions per minute	174
Cutting off steam at, in.	4
Area of exhaust nozzle, in.	19 6-10

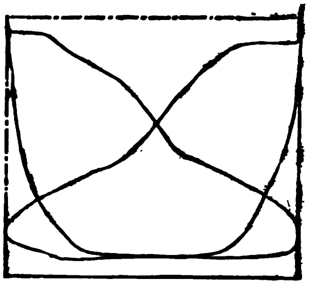

Fig. 143.

Steam pressure on boiler, lbs.	130
Throttle	wide open
Revolutions per minute	260
Cutting off steam at, in.	10
Area of exhaust nozzle in.	19 6-10

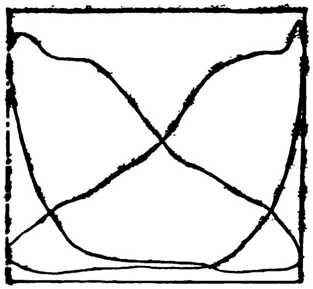

Fig. 144.

Steam pressure on boiler, lbs.	135
Throttle	open $\frac{1}{2}$
Revolutions per minute	235
Cutting off steam at, in.	8
Area of exhaust nozzle, in.	19 6-10

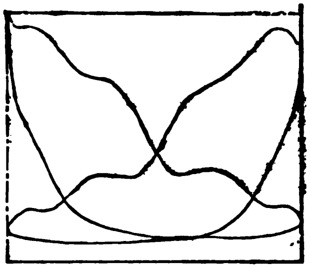

Fig. 145.

Steam pressure on boiler, lbs.	125
Throttle	wide open
Revolutions per minute	320
Cutting off steam at, in.	8
Area of exhaust nozzle, in.	19 6-10

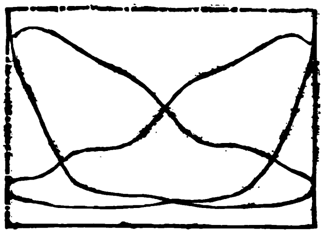

Fig. 146.

Steam pressure on boiler, lbs.	110
Throttle	wide open
Revolutions per minute	340
Cutting off steam at, in.	9
Area of exhaust nozzle, in.	19 6-10

The diagrams from Fig. 147 to Fig. 157 are taken from a locomotive engine on the Philadelphia and Reading railroad which had the Joy valve gear. The dimensions of the engine are as follows:

Cylinders	21 inches diameter; 22 inches stroke.
Four driving wheels	67¼ inches diameter.
Total heating surface	1137 square feet.
Grate area	76 square feet.
Weight on driving wheels	64,250 pounds.
Total weight of engine	98,200 pounds.
Lead on steam port	¼ inch.

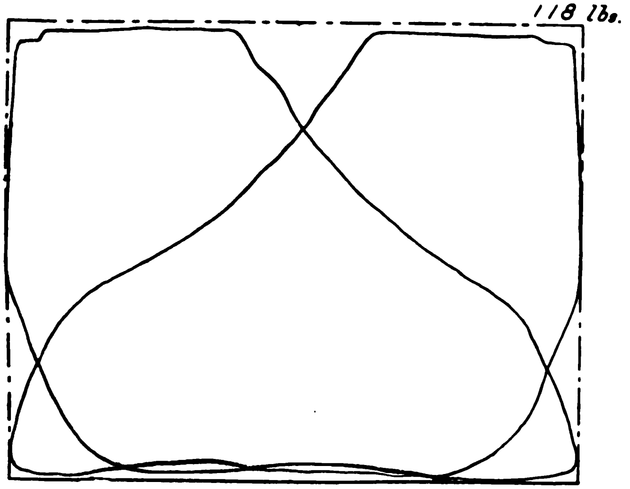

Fig. 147.

Steam pressure on boiler, lbs.	118
Revolutions per minute	72
Cutting off steam at, in.	9⅝
Exhaust nozzle area sq. in.	19
Miles per hour, about	14.3

Throttle wide open.

When the first four (Figs. 147, 148, 149 and 150) were taken the valve had but ⅛ inch lead, and the result is plainly marked on the diagram, where it is seen that the admission was imperfect and the imperfection is more plainly marked as the links were hooked up for the earlier cut-off, and at one end more than at the other. Thus on the right hand end of

Fig. 149 it is seen that after the point A, where the lea opened; the piston moved some distance before the steai pressure reached the highest point shown on the diagram.

The Reason that the Diagram for one end, varies froi that for the other end of the cylinder, is that the engin settled down somewhat upon her springs.

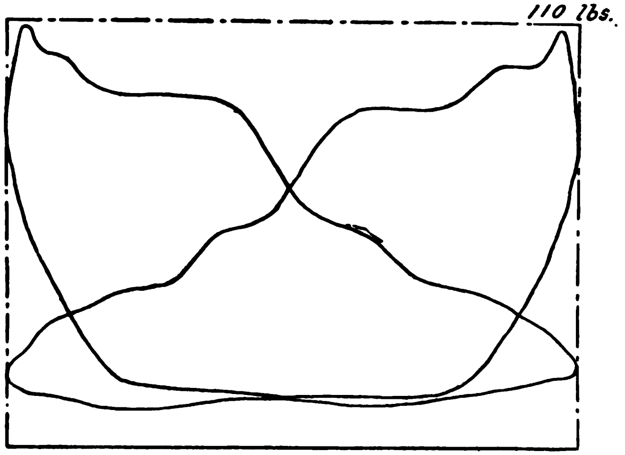

Fig. 148.

Steam pressure on boiler, lbs.	110
Revolutions per minute	186
Cutting off steam at, in.	9⅝
Exhaust nozzle area, sq. in.	19
Miles per hour, about	37
Throttle wide open.	

In more improved applications of the Joy valve gear thi disturbing element is eliminated.

The Effect of Increasing the lead is plainly shown i Figs. 151, 152, 153 and 154, the admission being greatl improved.

The effect of using a heavy indicator spring is also illu trated in these four figures, as the lines are less waved, and the vertical height of the diagram is reduced.

Diagrams at Higher Speed are shown in Figs. 155, 156 and 157.

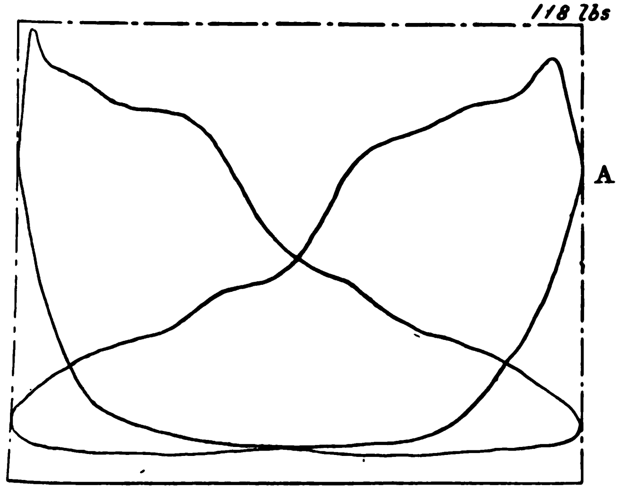

Fig. 149.

Steam pressure on boiler, lbs.	**118**
Revolutions per minute	**218**
Cutting off steam at, in.	**9⅝**
Exhaust nozzle area sq. in.	**23**
Miles per hour, about	**43.4**
Throttle wide open.	

It will be observed that in the left hand diagrams the lead still seems deficient, the defect appearing most strongly marked in Fig. 156, but appearing also in Fig. 155 at both ends. In Fig. 157 the line of back pressure is higher on account of the exhaust nozzle being closed more, and the higher speed the engine was running at.

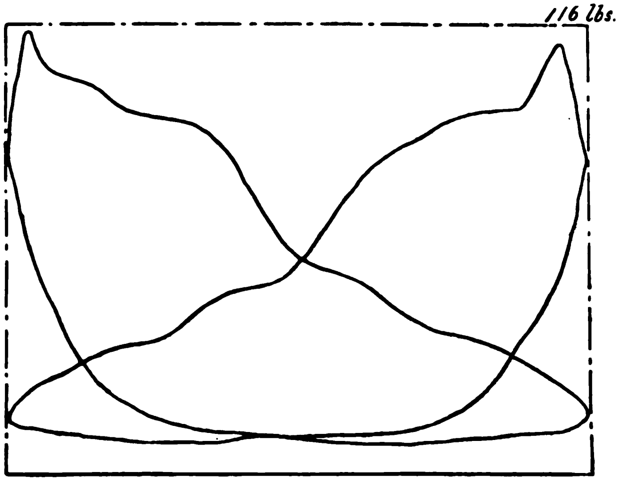

Fig. 150.

Steam pressure on boiler, lbs.	116
Revolutions per minute	232
Cutting off steam at, in.	$9\frac{5}{8}$
Exhaust nozzle area, sq. in	23
Miles per hour, about	46.1

Throttle wide open.

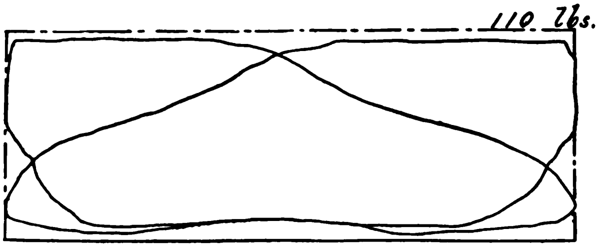

Fig. 151.

Revolutions per minute	104
Cutting off at, in.	$11\frac{1}{4}$
Miles per hour, about	20.7

Throttle wide open.

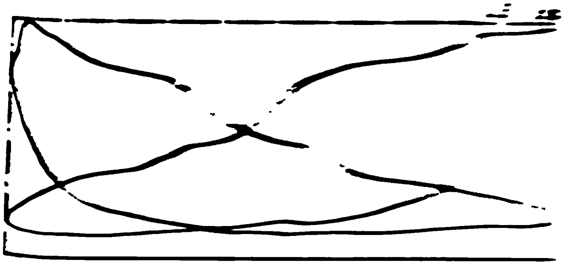

Fig. [illegible]

Revolutions per minute . . . . [illegible]
Cutting off steam at [illegible] [illegible]
Exhaust [illegible] [illegible]
Miles per hour [illegible] [illegible]
Throttle wide open.

The Following Diagrams [illegible] tive having the [illegible]

Diameter of cylinder [illegible] inches
Length of stroke [illegible]
Diameter of driving wheels [illegible]
Travel of valve [illegible]
Outside lap of steam [illegible]
Inside lap of exhaust [illegible]
Scale of indicator spring 40 lbs. per inch.

The Boiler Line [illegible] boiler pressure and is drawn as follows:

While the Engine is Standing Still with the throttle valve wide open, steam is admitted from the steam-chest to the indicator and the indicator drum is revolved by pulling its cord by hand, hence the indicator marks the line of H.

Or the Boiler Line May be Drawn by Hand, being parallel to the atmospheric line and above it to a distance that measures on the scale of the indicator showing a distance equal to the boiler pressure as indicated by the steam gauge.

Particulars for the diagram shown in Fig. 154.

Revolutions per minute	**240**
Cutting off steam at, in	**$5\frac{3}{4}$**
Miles per hour, about	**47.7**
Throttle half open	

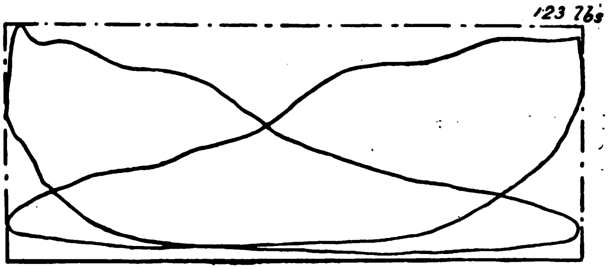

Fig. 155.

Revolutions per minute	243
Cutting off steam at, in	$7\frac{5}{8}$
Exhaust nozzle area sq. in	25 9-10
Miles per hour, about	47.7
Throttle wide open.	

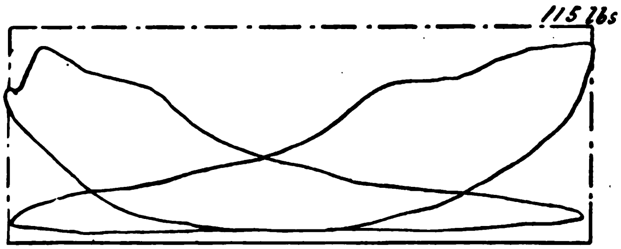

Fig. 156.

Revolutions per minute	300
Cutting off steam at, in	$5\frac{7}{8}$
Exhaust nozzle area sq. in	25 9-10
Miles per hour, about	59.7
Throttle wide open.	

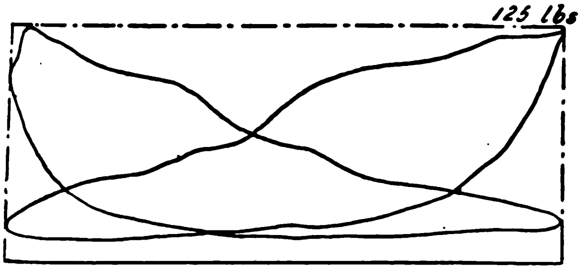

Fig. 157.

Revolutions per minute	333
Cutting off steam at, in.	$7\frac{5}{8}$
Exhaust nozzle area sq. in	19
Miles per hour, about	66.2

Throttle wide open.

The Following Diagrams are from a passenger locomotive having the dimensions below·

Diameter of cylinder	18	inches.
Length of stroke	22	"
Diameter of driving wheels	66	"
Travel of valve	$4\frac{3}{4}$	"
Outside, or steam, lap	$\frac{3}{4}$	"
Inside or exhaust lap	$\frac{1}{8}$	"

Scale of Indicator spring 40 lbs. per inch.

The Boiler Line G H, represents in all the diagrams the boiler pressure, and is drawn as follows.

While the Engine is Standing Still with the throttle-valve wide open, steam is admitted from the steam-chest to the indicator, and the indicator drum is revolved by pulling its cord by hand, hence the indicator marks the line G H.

Or the Boiler Line May be Drawn by Hand, being parallel to the atmospheric line, and above it to a distance that measures on the scale of the indicator showing a distance equal to the boiler pressure as indicated by the steam gauge.

Suppose, for example, that a 40 lb. spring is used in the indicator and that the boiler pressure by gauge is 80 lbs., then the line G H would be drawn 2 inches above the atmospheric line, because $8 \div 40 = 20$, or in other words, the boiler pressure shown by the steam gauge divided by the scale of the spring, gives the height in inches that the boiler line stands above the atmospheric line.

The steam line of a diagram does not, under favorable conditions, meet the boiler line but falls not less than 5 lbs. below it, and in throttling engines, considerable more.

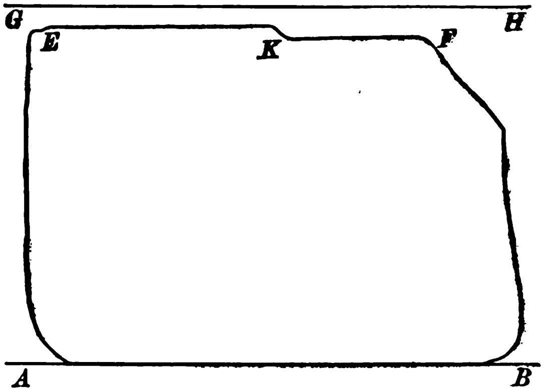

Fig. 158.

The engine being started and steam from the steam-chest being admitted to the indicator, it will draw upon the card or the diagram a line indicating whatever fluctuation of pressure occurs in the steam-chest, this line of steam-chest pressure being shown in some of the following diagrams.

With the Link in Full Gear and the engine just started, the diagram, Fig. 158, was made, as the scale of the indicator was 40 lbs. per inch, then the steam-chest pressure may be obtained by multiplying this 40 by the distance in inches and parts of an inch.

Thus suppose line G H measured three inches (as it does on the diagram, the engraving having been reduced), from line A B and it would represent 120 lbs. as the steam-chest

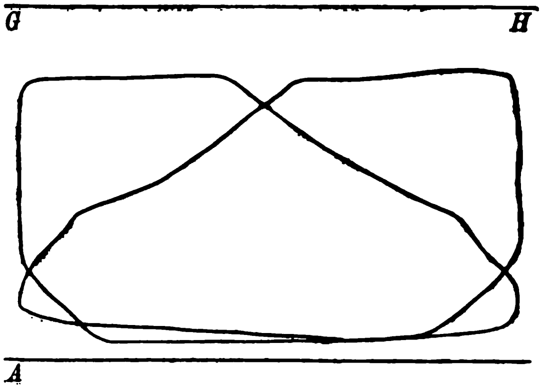

Fig. 159.

pressure because three times forty are one hundred and twenty.

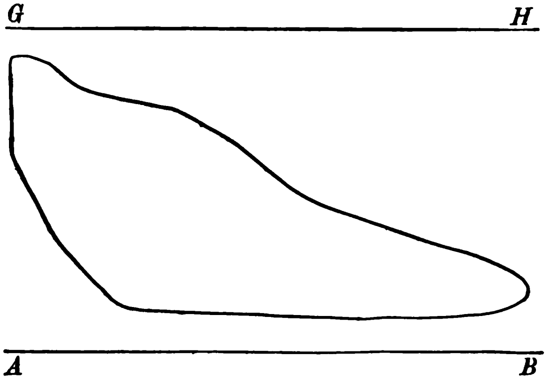

Fig. 160.

The Sudden Fall of the steam line of the diagram at the point K was caused by the steam port of the other cylinder opening and causing the pressure in the steam-chest to reduce.

The point of release is obviously at F.

Fig. 159 was taken with the link motion hooked up so as to cut off at half stroke, the engine making about 100 revolutions per minute.

It Will be Seen in this card, that the pressure during the admission or live steam period, fell far short of chest pressure, and the exact amount may be found by measuring the distance between the top of the diagram and the line G H, and multiplying it by the scale of the indicator spring, thus suppose the above distance measures half an inch, and if we multiply 40 (the scale of the spring), by ½ or .5, we get 20, and 20 lbs. will be the difference between the boiler pressure and the pressure in the cylinder before the point of cut-off.

It is here seen also, that the exhaust is not entirely free. above the atmospheric line A.

To find the amount of back pressure at any particular point in the stroke, we measure the distance, at that point between the exhaust and atmospheric lines and multiply it by the scale of the indicator spring, thus suppose at some one point in the stroke the distsnce between the exhaust line and the atmospheric line measures ¼ inch, and we divide the scale of the spring by 4, getting 10 lbs. per square inch as the amount of back pressure at that particular point in the stroke.

The Reason there is back pressure, is because the engine was making 100 revolutions, and there was not sufficient time for the steam to pass unobstructed through the exhaust nozzle.

With the Link Hooked Up to cut off at about ⅓ stroke the diagram Fig. 160 was taken, the revolutions being 200 per minute, and it is seen that the steam line does not, during the live steam period, keed parallel to the line G H as it should do.

This is Caused by the Steam port Not Opening wide enough, and is a defect incidental to all flat valves which are single ported, and have their travel reduced so as to cut-off early in the stroke, whether the reduced travel is obtained by a link motion or by any other means, as, for example, by shifting the eccentric across the shaft.

A diagram from the steam-chest, when the engine was first starting, is shown in Fig. 161, the steam being cut off at $\frac{1}{3}$ stroke.

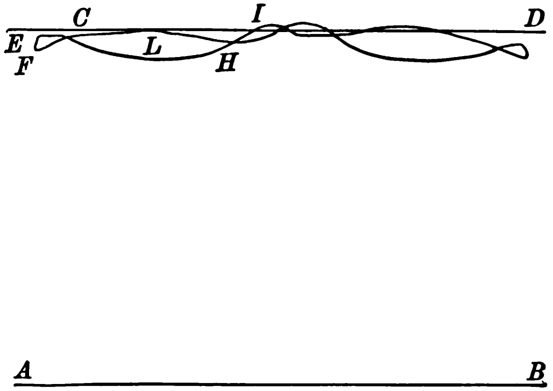

Fig. 161.

At the beginning of the stroke the pencil stood at E, and as the port opened the pressure fell until the point L was reached where it is the least.

Steam Was Cut-Off at H and the pressure then rose, finally reaching I which is above the boiler pressure, which occurred because of the arrest of the motion of the steam in the steam pipe.

When the port for the other cylinder opened the pressure again fell.

Fig. 162 is taken from a steam-chest, the throttle valve being partly closed and the engine making about 200 revolutions per minute, with the cut-off at one-third of the stroke, and it will be seen that the steam-chest pressure remained nearly uniform but below boiler pressure on account of the throttling.

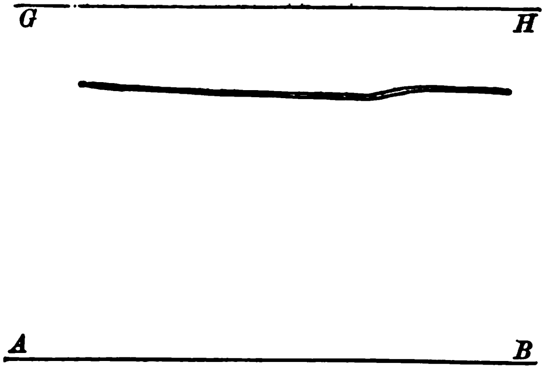

Fig. 163.

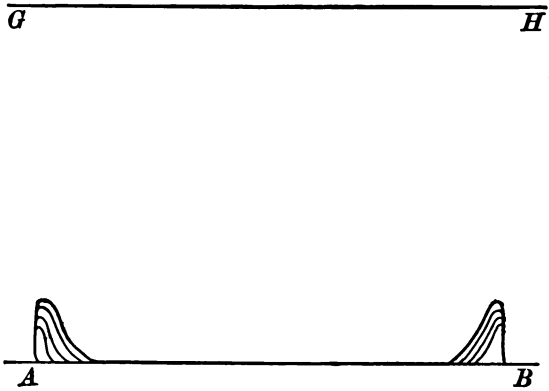

Fig. 164.

A Diagram From the Exhaust Port is shown in Fig. 163, the cut-off having occurred at one-third stroke and the engine just started, hence the exhaust is free on account of the slow piston speed. Fig. 164 is from the exhaust port with the cut-off at $\frac{1}{3}$ as before, but with the engine wheels making about 160 revolutions, hence the steam had less time to escape, and there is therefore back pressure.

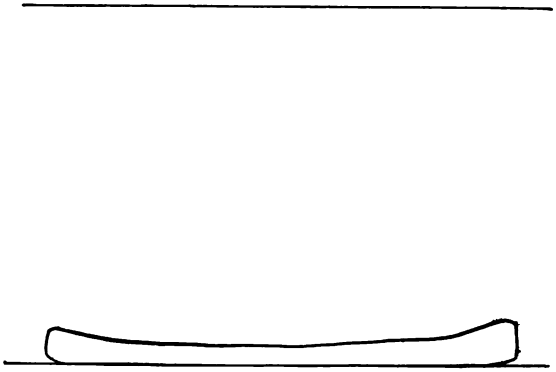

Fig. 164.

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